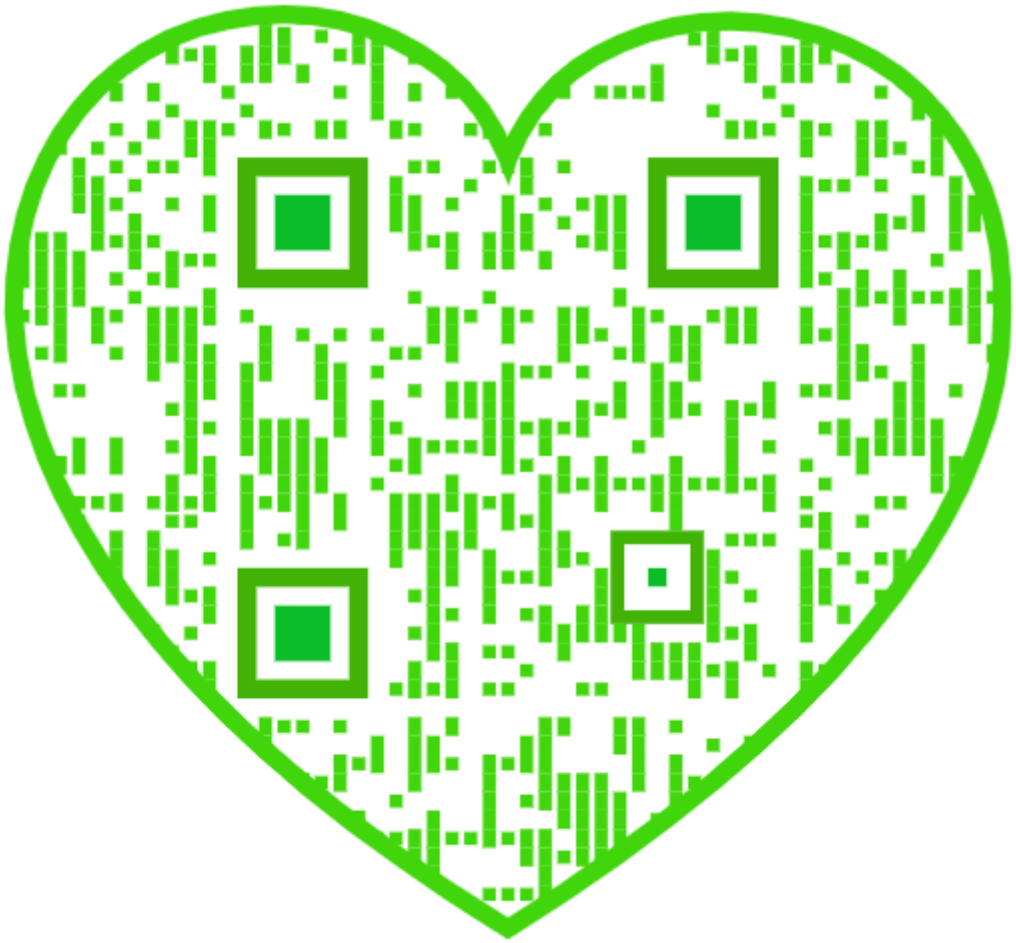

EXTRA CENSUS BULLETIN.

REPORT

ON THE MANUFACTURE OF

FIRE-ARMS AND AMMUNITION

BY

CHARLES H. FITCH,
SPECIAL AGENT.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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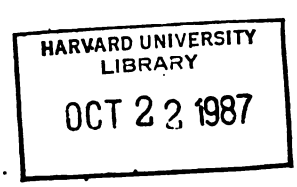
Museum of
Comparative Zoölogy



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LETTER OF TRANSMITTAL.

NEW HAVEN, CONN., *October* 1, 1881.

Hon. FRANCIS A. WALKER,
Superintendent of Census.

DEAR SIR: I have the honor to transmit herewith the reports of Mr. Charles H. Fitch, of New Haven, Connecticut, special agent of the Tenth Census, on the interchangeable system of manufacturing in the United States.

Mr. Fitch, a graduate of the Sheffield Scientific School of Yale College, was selected for this duty from my personal knowledge of his acquirements and his unfailing industry and zeal in whatever work he is called upon to do.

The general growth of the "interchangeable system" in manufacturing, which it was your wish to include in the statistics of power and machinery, has had an influence in the development of manufacturing, agricultural, and other industries which but few have heretofore appreciated. It may not be too much to say that, in some respects, this system has been one of the chief influences in the rapid increase in the national wealth. Two of the great industries which constitute the basis of this wealth, agriculture and manufactures, depend now largely upon the existence of this remarkable feature in manufacturing, which has reached its highest development in this country. The growth of the system is due to the inventive characteristics of our people, and their peculiar habit of seeking the best and most simple mechanical methods of accomplishing results by machinery, untrammeled by traditions or hereditary habits and customs.

The practice of making single objects of general utility, such as steel-pens, pins, and needles, by machinery or by successive processes, in which different workmen have special operations to perform in succession on the same object before it is completed, is an old one. The art of making complete machines or implements, each part of which may be introduced into any machine of the same kind, and especially the adaptation of special tools, by which hand-work in fitting the parts is often entirely avoided, is, I believe, of American origin.

The gradual change which has taken place in methods of farming during the last twenty or thirty years has been chiefly due to the fact that the farmer can now supply himself, at reasonable cost, with machines or implements which reduce manual or muscular exertion to a minimum, and render almost a pastime work which formerly taxed his endurance to the utmost.

The introduction of these machines and implements has, moreover, reduced waste and effected economy in production. The manufacturer is now able to furnish the modern agricultural implements to the farmer at reasonable cost only through the peculiar system of manufacture which is now followed, it being possible to furnish such machines at low prices only by making the separate parts of each machine in large numbers or quantities, by means of special tools, and assembling the parts which are required for a complete machine at a single and separate operation.

This constitutes the fundamental idea of the interchangeable system. One of the direct results of the system has been, moreover, a great improvement in the strength, durability, and working performance of the machines thus made.

These two great interests, agriculture and manufacture, have thus reacted upon each other. While, on the one hand, there has been a great increase in the manufacture of such implements to supply the demand created, on the other hand agricultural processes have become to a large extent but the application of labor-saving or labor-multiplying machinery, requiring more exercise of the intellectual faculties and less of muscular force.

Perhaps the most conspicuous illustration of the capabilities of this system of manufacture is found in the sewing-machine; a machine so complicated in some respects in its mechanism, and requiring such a perfect adjustment of its parts, that it is doubtful whether it could be made *by hand* with its present qualities of durability and perfect action under long-continued use. Yet these machines find their way into the homes of the poor as well as of the rich, and through years of continual use are always ready and never-failing in their action.

To the special tools by which the parts are made, and the interchangeability of the parts, may be attributed the growth of a new manufacturing industry and the great benefits which have been derived from the invention of this useful machine.

I need but refer to other branches of manufacture, such as watches, fire-arms, railroad cars, and locomotives, of which great numbers, identical in parts and dimensions, are to be made; all such constructions are now produced to a greater or less extent under the application of this system. It may be said that a new business principle has been introduced into the art of machine manufacture, viz, that diminished cost and more perfect workmanship may be secured by interchangeability of parts, and for certain kinds of manufacture the carrying out of this principle is essential to financial success.

Very respectfully, your obedient servant,

W. P. TROWBRIDGE,
Special Agent.

I a.

FIRE-ARMS.

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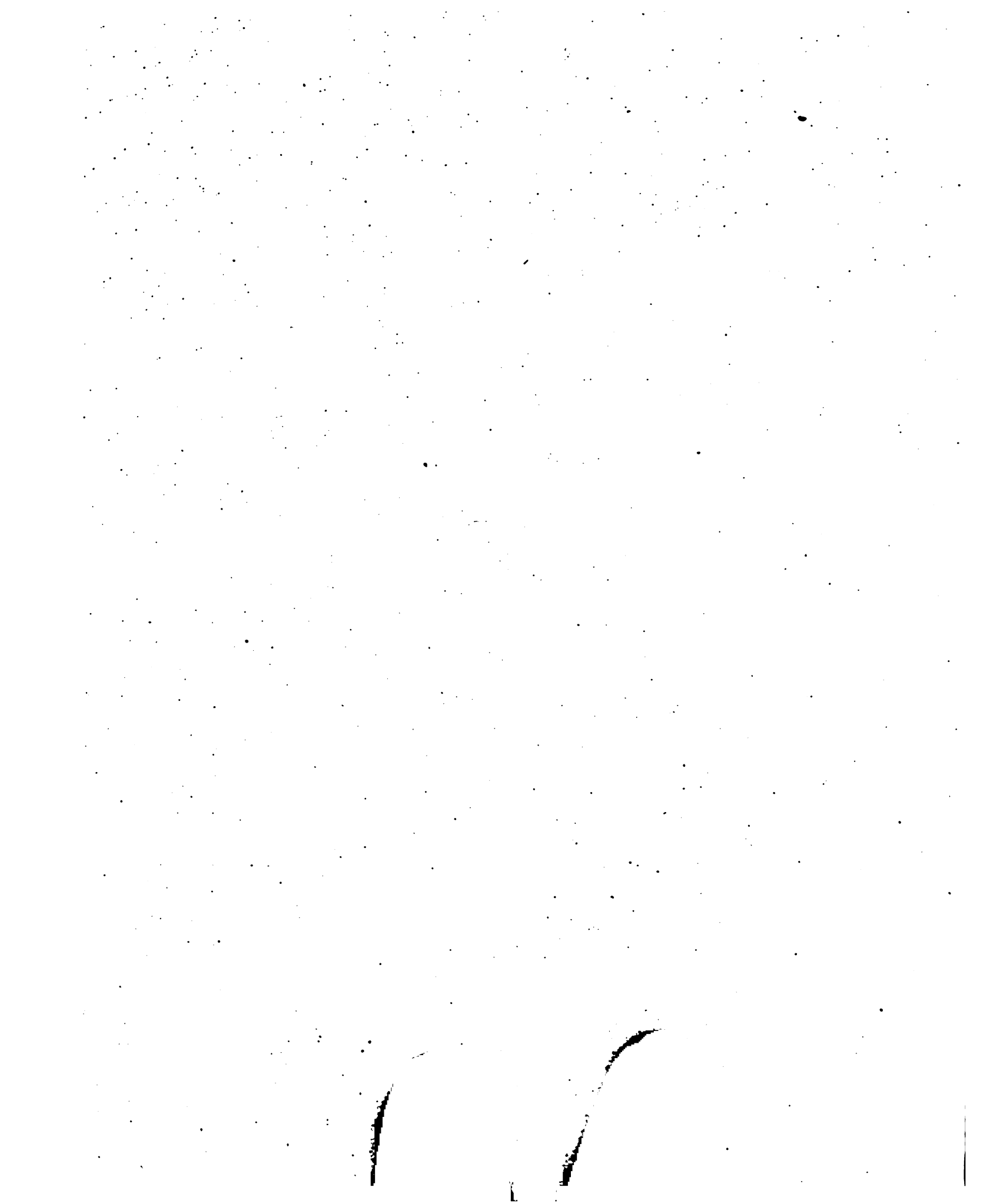

PART I a.—FIRE-ARMS.

TABLE I.—THE MANUFACTURE OF FIRE-ARMS IN THE UNITED STATES.

State.	No. of establishments.	Capital.	Greatest number of hands employed at any one time during the year.	Average number of hands employed.			Total amount paid in wages during the year.	Materials.	Products.
				Males above 16 years.	Females above 15 years.	Children and youths.			
The United States	38	$8,315,289	5,491	4,579	87	181	$2,560,089	$1,781,326	$5,618,636
Connecticut	12	3,485,834	2,690	2,272	85	102	1,309,375	753,386	2,470,398
Maine*	1	200,000	.....	.....	.....	.....	.....	.....	.....
Massachusetts	12	3,321,455	1,274	1,092	1	29	619,816	342,655	1,158,227
New York	5	788,000	521	489	.....	24	291,500	84,000	823,500
Pennsylvania	7	160,000	196	173	1	3	75,150	50,500	175,400
Rhode Island	1	360,000	810	553	.....	23	264,248	550,785	991,111

*1 establishment in Androscoggin county; not in operation during census year.

HISTORICAL AND DESCRIPTIVE SUMMARY.

THE MATERIALS USED.—In the manufacture of fire-arms the relative cost of constituent materials varies with the character and finish of the product. With a fine grade of sporting guns it is sometimes as small as 3 or 4 per cent. of the value of the product. In one instance, of all the constituent materials used, by weight, about 90 per cent. was domestic decarbonized steel at 6 cents, 5 per cent. foreign steel at 15 cents, 4 per cent. iron and steel wire at 8 to 40 cents, and 1 per cent. Norway and refined iron at 6 to 9 cents per pound.

Some parties import all their gun-iron and nearly half their steel; but the percentage of foreign iron and steel used is, on the whole, small, some concerns using American iron and steel only. The gross weight of the material used is sometimes double the net or finished weight. Refined iron was once the principal material in gun-making, but it is now almost displaced by decarbonized steel. In 1826 cast-steel was considered a curiosity; blacksmiths were unable to weld it, and it was not used for bayonets, ramrods, and springs until after 1842 in either national or private armories.

The cost of constituent material, relative to the product, is sometimes upward of 13 per cent., being usually greater for pistols than for guns, greater for cheaper than for more finished grades of arms, and greater for military rifles made in large quantities than for sporting guns manufactured with less wholesale facilities.

The principal mill supplies are fuel, tools, oil, files, emery, glue, and soda. An average equivalent of about 3 tons of coal per annum per operative is required in the latitudes of Connecticut and Massachusetts, about 20 per cent. being estimated for heating purposes in factories during the year. The fuel required for power is, as in other manufactures, usually in excess of the best economical results obtainable with good stoking and the most suitable boilers and engines.

In the returns for establishments classified as fire-arm factories the ratio of material to product will be found to have a wide range. This variation is due partly to the incessant fluctuations of the metal market, both local and general, and partly to the inclusion of manufactures of sewing-machines, ammunition, hardware, and machinery (having a higher relative cost of material); but there is sometimes a marked appearance of inconsistencies in making the returns, the cost of material being, as reported in some cases, barely sufficient to cover the purchase-price of of constituent materials, while in others it assumes a relative value, which would indicate that the cost of new machinery or other expenses were included.

THE GENERAL CHARACTER OF THE WORK.—The manufacture of fire-arms comprises the fabrication of a great number and variety of parts, and the assembling of these parts into arms. The making of gun-barrels and stocks may be conveniently considered as separate departments of the work; but the lock-systems and other small parts exhibit such variety, both among themselves and in the different arms manufactured, that their fabrication may be better classified in respect to the similar kinds of work done upon them, rather than in regard to the pieces themselves.

The detail of the methods of operation is a variable matter, exhibiting in different armories, and in different parts of the same armory, different methods of effecting similar results, with all the variation in productive efficiency thereby entailed. From month to month, and from week to week, the ingenuity of foremen and of contractors is applied to improve these details. Some classes of automatic machinery, involving a heavy outlay, obtain a high output, and are only profitable on heavy orders, and, when these fall away, the less efficient but less expensive usages are resumed. Some of the changes introduced by individual ingenuity are found to be experiments, rather than improvements.

While these transitions may prevent the utmost exactitude in general statements of the condition of the industry, its outline may still be fairly drawn. As a prelude to such presentation of the subject, an account is introduced of the growth of the interchangeable or uniform system, which has so notably modified the character of the manufacture, both in its mechanical and in its administrative features.

THE DEVELOPMENT OF THE AMERICAN SYSTEM.—The development of the interchangeable system has been a gradual process, extending over a considerable period of time. Sample guns, with parts to interchange, had been made in France as early as 1717, and again in 1785, at each of which dates the attempt to reduce this desirable feature to a practical manufacturing result failed, presumably through prejudice, improper system, and lack of machinery. Eli Whitney, the inventor of the cotton-gin, who took up the idea in this country about the beginning of the present century, systematized the work, and by making the parts in lots of large numbers, employing unskilled labor for filing them to hardened jigs, and by close personal supervision, succeeded in executing a contract under circumstances which caused the failure of other contractors, who employed skilled craftsmen, filers, and gunsmiths to do the work. While with him, as with the gunsmiths of that time, the stocks were made by hand shaving and boring, the barrels were forged by hammers upon anvils and finished by rude drills and by grindstones, and the lock parts were ground and drilled and filed approximately to patterns and fitted together; he also made the lock parts more uniform by the systematic use of hardened jigs, and classified the work on a more intelligent and economical basis. If gun parts were then called uniform, it must be recollected that the present generation stands upon a plane of mechanical intelligence so much higher, and with facilities for observation so much more extensive than existed in those times, that the very language of expression is changed. Uniformity in gun-work was then, as now, a comparative term; but then it meant within a thirty-second of an inch or more, where now it means within half a thousandth of an inch. Then interchangeability may have signified a great deal of filing and fitting, and an uneven joint when fitted, where now it signifies slipping in a piece, turning a screw-driver, and having a close, even fit. Gunsmithing was a great craft at that time. There were separate establishments for the manufacture of gun-barrels, and armorers were scattered through the country, as blacksmiths now are, and some of them had a local notoriety for the cunning work of their hands. But whatever of mechanical ingenuity may have been devised at this period, in default of more specific evidence, general accounts of machinery remarkable in design and precise in operation can be construed to signify little more than drills and boring and slabbing machines of a rude description.

The making of arms with interchangeable parts continued to be attempted, although generally held to be impracticable. In 1812 it is stated that alarm was taken at the rapid increase of damaged muskets on the hands of the government. Whitney, Hall, North, and other contractors exhibited samples of interchangeable work at early dates, and the desirability of interchangeable work seems to have been very generally expressed. In 1815 it was recommended by Colonel Wadsworth, after advising with Messrs. Stubblefield, of Harper's Ferry, Prescott & Lee, of Springfield, and Whitney, of New Haven, that pattern muskets and rifles be made and distributed to the various armories, public and private, for the purpose of insuring practical uniformity, no deviation from the patterns to be tolerated after the work in hand should have been finished off.

The assembling of the lock parts is considered a crucial test of interchangeability. After hardening, the parts cannot well be filed or milled. If, then, they are hardened before fitting, the parts must be made interchangeable; but if they have to be first assembled and fitted soft, and the same parts have to be marked or kept separate to avoid mixing after hardening, it is evidently on account of a lack of uniformity.

It is stated that in 1814 Colonel North, at Middletown, Connecticut, commenced the manufacture of pistols whose lock parts were made so uniform that they did not require to be assembled and fitted soft, as was then the usual practice. In 1819 Hall commenced practical operations at Harper's Ferry, and in 1827 had so far perfected his improvements that a report made by three gentlemen, Messrs. Carrington, Sage, and Bell, to Colonel Bomford, testifies that 100 Hall rifles, made in 1824, were stripped and the metal parts mixed and remounted on 100 new stocks, the parts all coming together well. This notable achievement, so well authenticated, is the more notable

because it appears to have been due to the machine methods employed by Hall; to the die-forging, and to the system of making machine-cuts for all the essential fits, rather than to ordinary forging and hand-filing. The joints were not close, nor was the work fine, but the interchangeability was a practical fact, and uniformity was approached on a more sustained plan than that of merely filing to jigs or patterns. The joint of the breech-block was so fitted that a sheet of paper would slide loosely in the joint, but two sheets would stick.

From 1817 to 1822 the improvement in manufacture at the national armories was stated, considering the better workmanship and uniformity, to involve an advantage of 20 per cent. This was the period of the introduction of barrel-turning, forging under trip-hammers, and the Blanchard method of machining stocks. Yet even then the pattern rifles furnished to guide contractors and insure practical interchangeability do not appear to have attained a high degree of uniformity themselves, for it is stated that after Colonel North commenced the manufacture of Hall's rifles, in 1823, he was furnished with two pattern rifles, which were found to be so unlike that one had to be thrown aside, while the work was gauged to the other; and it is said that some of the contractors used to stipulate for a case of pattern muskets, resting assured that if, upon inspection, any fault were found with the guns manufactured something equally defective could be found in the case to match it, and thus to define the degree of practical "uniformity" desired.

The Hall rifles made at Middletown appear to have been uniform, although the machinery of Hall's design was not used in making them. It is stated of those made by North that the locks were first assembled after hardening, that the stocks were machined without fitting the lock parts (the machinery being designed by Selah Goodrich on the Blanchard principles), and that after the Florida war a lot of damaged carbines thrown into the Watervliet arsenal were repaired, and the parts, old and new, interchanged without difficulty. In 1829 the Hall rifles, made by R. & J. D. Johnson, of Middletown, were referred to in an ordnance report as being of superior make. Inspection was now more thorough, and receiver-gauges were used. But the muzzle-loading muskets were still made at the national armories with the lock parts so far from uniform that a device of Blanchard's for adapting his stock-bedding machinery to conform to their irregularities was still in use.

In 1840 Thomas Warner, master-armorer, introduced improved methods and machinery at the Springfield armory. He secured interchangeable work by the use of milling machinery, by jig-filing, and by careful inspection. Receiver-gauges were used, and it is stated that at this time the locks were not marked for hardening. This improved system was introduced by Warner at Whitneyville in 1842, where, prior to this time, the locks had been assembled and fitted soft and marked for hardening in sets of ten.

In 1842 Albert Eames introduced interchangeable work in the manufacture of Jenk's carbine and pistol for the Ames Manufacturing Company. He used a fine set of gauges and jigs, and, on inspection, the efficiency of the system was repeatedly tested by stripping ten guns, mixing the parts, and reassembling them at random. In 1842 the manufacture of the new model percussion musket was begun at Springfield, and model jigs, taps, and gauges were provided for the work. Although from this time there was gradual improvement in the machinery used, the books of account for piece-work show that the custom of assembling and marking locks "soft"—that is, before the hardening process—in sets of ten was practiced at least from 1844 to early in 1849. In 1853, as a test before the British commission, Major Ripley ordered ten guns of the manufacture of ten years, from 1843 to 1853, to be stripped, and the parts mixed and reassembled promiscuously, which was successfully done. The practice of assembling locks "soft" appears to have been discontinued in 1849. A system of interchangeability largely dependent upon hand-filing is difficult to sustain, even with the aid of jigs. In the earlier attempts filing was the principal means of making interchangeable work; but the inspections were not then severe, nor were the pieces required to be so well made as to fit fine gauges. Filing close to hardened jigs is also very destructive of files—an important element of cost. It is scarcely a matter of wonder that the systems of interchangeability so repeatedly introduced were not well sustained until after the introduction of the practices of close forging with steel dies and metal-working, with efficient machinery for making sensibly exact cuts, without dependence upon the craft of the operative. Drilling with jigs is still the common practice, but filing to jigs was superseded by milling and edging with cutters, which were themselves formers, whose exactness was tested and maintained, in case of wear, by the careful gauging of the work. The present excellence of fine machine work enables almost any desirable degree of accuracy to be obtained, both in cutters and gauges. For ordinary work receiver-gauges, into which the work must fit accurately, are sufficiently nice, although for the finest work upon the dimensions of chambers and other parts, verniers, micrometers, and multiplying arrangements are often used. Limit-gauges, or, as they are called, go-in and not-go-in gauges, are in common use; that is, a set of two close gauges, one of which will receive a piece which will not go into the other, thus establishing a limit of accuracy both for openings and for exterior outlines. One hundred and fifty-four fine gauges are used in testing the accuracy of the parts of the Springfield rifle; that is, 154 pieces, many of them being so contrived as to gauge a great variety of measurements with a single instrument.

ADOPTION OF THE AMERICAN SYSTEM IN FOREIGN COUNTRIES.—At the world's fair of 1851, London, a number of Mississippi rifles, as made by Robbins & Lawrence, of Windsor, Vermont, for the United States government, were exhibited, and received the award of a medal. The locks of these were not marked for hardening, and their workmanship and uniformity attracted much attention. This exhibit, and the reports of the Blanchard stocking

machinery, caused the British government to send a commission to this country to examine the methods of manufacture. The interchangeable system, with its astonishing results and its ingenious plants of machinery, was still distinctively American. The inspection of its workings at Colt's armory, the national armory at Springfield, the Robbins & Lawrence armory at Windsor, Vermont, and other works, led to immediate orders for American machinery. In 1855 an American firm supplied British agents with 20,000 interchangeable Enfield rifles and several sets of machinery, the first comprising 157 machines, valued at $44,360 (exclusive of boxing, transportation, and sundries), and including 8 universal milling, 57 milling, 3 double-milling, 4 screw milling, 2 clamp-milling, 12 four-spindle drilling, 5 tapping, 7 edging, 8 drilling, 1 grooving, 2 squaring, 5 threading, 1 chucking, 1 broaching, 5 screw-slotting, 3 screw-pointing, 3 screw-clipping, 1 chasing, 3 six-spindle drilling, 2 screw-thread finishing, 1 punching, 1 hand-planing, 1 index-milling, 7 turning, and 2 rifling machines. These machines were extensively copied in England and in Germany. The universal milling-machine, which was designed by Frederick W. Howe in 1852, is found, in all essential features, illustrated in the London *Engineering*, nearly a quarter of a century later, as a machine of English design. The universal milling-machines were sold at $850 each; the plain milling-machines at $300 each. At the same time the stocking machinery at the Springfield armory had been found to handle with ease the tough stocks which were brought over to test its efficiency, and several English orders for stocking machinery were given to an American manufacturing company. Thus introduced, and manifesting its superiority beyond all question, large and numerous orders for American machinery followed, which were filled by various parties. Within the next fifteen or twenty years the governments of England, Russia, Prussia, Spain, Turkey, Sweden, Denmark, Egypt, and other countries were supplied with American machinery for the manufacture of arms, while its essential and labor-saving features have been introduced and copied throughout the civilized world. The civil war gave a tremendous impetus to arms manufacture in this country, and after its close the capital invested sought a foreign market, and millions of arms were exported. In 1867 the visit of agents of the Danish government to E. Remington & Sons resulted in a contract for between 35,000 and 40,000 arms, with machinery for their manufacture. In the same year the Swedish government contracted for 10,000 arms, 20,000 lock-systems, and machinery for their manufacture. In 1868 the Spanish government contracted for arms. In 1869 the Egyptian government ordered 60,000, and later 100,000 additional guns, and machinery for a gun-factory, to be built at Alexandria (an order never completely filled). Japan, the Argentine Republic, Chili, Peru, Mexico, and other countries have been largely supplied from the same source.

During the Turkish war both the Russian and the Turkish governments were very heavily supplied with arms and munitions of war from American armories, notably by the Winchester Repeating Arms Company, of New Haven, Connecticut; the Providence Tool Company, of Providence, Rhode Island, and the Union Metallic Cartridge Company, of Bridgeport, Connecticut. Perhaps no more creditable instance could be adduced of the superiority of the best American gun machinery than is furnished in the supply by the Pratt & Whitney Company, of Hartford, Connecticut, of gun-making plants for the Prussian government armories at Spandau, Erfurt, and Danzig. This machinery was designed to execute all the work upon parts of the Mauser rifle, except the stocking and part of the barrel-making. A testimonial was furnished by the Prussian government, expressing its satisfaction with the work, from which a few sentences (in translation) may be properly quoted. The paper was dated April 27, 1875, and stated that "the said machinery and tools were to furnish the parts of the guns automatically, and with such precision of finish as to render them fit for the polishing process without hand-work"; and also of the machines, "that the system upon which they are founded has rendered the government in no small degree independent of the skill and power of the workmen. In addition, a very material economy has been obtained, amounting already to one-half of the wages formerly paid."

Nor should it be considered that the methods displaced with such advantage were so very rude or primitive. Milling and profiling machinery was in general use, and the other machines were at least of a fair order, although susceptible of great improvement, as the above statements would plainly indicate. About the same time the Prussian government was furnished by the Billings & Spencer Company with 42 tons of finished dies for forging gun parts. But instances such as the foregoing only indicate a tithe of the world's indebtedness to American machinery and system in gun-making, methods and machines being introduced only to be followed and duplicated upon a more extensive scale.

THE CONDITIONS OF UNIFORM MANUFACTURE.—A large demand assured, and fine workmanship required, are the prime conditions of a uniform system. These conditions first existed in a pre-eminent degree only in gun manufacture under government contracts. The advantages of the system in making fine workmanship profitable in kindred manufactures secured extensive profitable markets for the manufacturers first availing themselves of it, while the advance in the conditions of comfort and convenience, due largely to this very agency, has continued by increased demands to advance the practice of the interchangeable system.

THE RETURNS OF CAPITAL.—Inadequate returns of capital employed in the manufacture of fire-arms are sometimes due to the fact that, while parties owning their real estate report its full value, parties renting it will report only such capital of current funds as may provide for the rental for a short period. In one case of a large factory, the main shaft and part of the machinery were found to be reckoned with land and buildings as real estate, all being leased from the heirs of the former proprietors—a capital as actively employed as ever, but practically withdrawn from the personal or corporate return of the parties manufacturing. Work-room and facilities can be

provided at a lower rate per man for a large than for a small number of operatives, but the return of capital per operative is usually less for a small shop.

Overratings, on the other hand, may be considered to result from the inclusion of capital foreign to the purpose of the manufacture, as is notably the case in the return from Hampden county, Massachusetts, which exhibits a high rating of capital, due to the inclusion of the extensive arsenal property of the government. It is also obvious that returns may be properly augmented beyond the usual average per operative by the high valuation of real estate in cities, and by plants of machinery disused, but still potentially capital. The valuation of real estate, carrying of stocks, and funds for running expenses, present so many special conditions that these requirements cannot well be generalized. For gun-work, the cost of machinery alone (exclusive of engines and boilers, the cost of which, in proportion to the number of power-machines, is much greater in a small than in a large factory) will average from $300 to $350 per operative, tools and fixtures costing half as much more. In some cases noted, hangers and shafting cost $8 to $12 per power-machine, and belting about half as much; and in one large factory the investment for steam and water piping is as great as for pulleys, hangers, and shafting.

In this connection one matter ought to be distinctly emphasized. The capital return is no indication of the capability of this country to produce small-arms in case of an emergency. Large plants of gun-machinery exist which are but partially used, and which are returned at a greatly reduced valuation, and, in addition to this, the vast plants of machinery employed in the manufacture of sewing-machines and other light mechanism could be diverted to arms manufacture with a great degree of facility.

THE DIVISION AND EFFICIENCY OF LABOR.—In large gun factories, under the stimulus of heavy orders, the finest military rifles are sometimes produced at the rate of 200 per annum per operative employed, on the basis of 312 working days of ten hours each in the year, and the operative labor is divided among the several departments in proportions roundly expressed in the following percentages: Making stocks, 6⅔ per cent.; barrels, 15 per cent.; locks and other parts, 66⅔ per cent. (comprising forging, 11¼ per cent.; filing, 9¼ per cent.; machining, 36⅔ per cent.; polishing, 7⅔ per cent.; sundry processes, 1⅔ per cent.); and inspection, assembling, and proof, 11⅔ per cent. Different factories present different requirements and divisions of labor, filing, for example, often requiring a smaller proportion than stated of the whole number of operatives. In addition to this there is some clerical and common labor—packing, teaming, and the like—and a small but important factor of special tool-making. The variation in such estimates, due to difference in breech-loading systems, is considerable, but for purposes of general statement may be considered to fall within such limits of workmanship and productive facilities as cannot be satisfactorily defined.

The effect of wholesale manufacture may be expressed in the estimate that, in manufacturing at the rate of 1,000 rifles a day, 3 men will do as much work as 7 to 9 men in manufacturing at the rate of 50 a day. Some of the methods commonly in use in the two cases, as generally practiced in this country, might be contrasted as follows: In the former, the barrels would probably be rolled down from drilled molds upon mandrels; in the latter, they would probably be drilled full length (a method preferred by some manufacturers in any case). In the former, the stocking would be more thoroughly done by machinery, while in the latter the chisel and the file would do a larger proportion of the work. In the former there would usually be two-thirds as many men as machines, and in the latter two-thirds as many machines as men, while much time would be wasted in waiting for machines to finish their work, in changing the appliances of milling-machines, and in changing operatives from one kind of work to another.

But either extreme of present usage stands in sufficiently marked contrast with the practice in 1819, when it was stated (*Ordnance Reports*, vol. 1, p. 57), in evidence of the superiority of American methods, that 250 men would at the national armories fabricate 12,500 stand of arms a year, while as many men were required for the fabrication of 10,000 stand in French armories. Nor can these rates of 40 and 50 muskets per operative per annum be compared with the numerical output of fine breech-loading rifles of to-day, for if present facilities were applied to the wholesale manufacture of these old muzzle-loading muskets an output of over 300 per operative per annum could easily be attained. The division of labor at that time was also very different. So far as machinery had been introduced, its construction was rude, and its use exceptional. Hand-shaving and chiseling for the stocks, and hand-forging, grinding, and hand-filing for the metal parts, constituted nearly all of the work. The filers—skilled workmen—were then mostly foreigners, and the consumption of files was enormous.

Apart from all consideration of the earliest usage of specific machines, it must be said that their introduction did not make itself felt as a great industrial agency until within twenty-five years past, in instance of which it may be stated that in 1839 there were at the Springfield armory about six men to one machine, and the ratio at other works seems to have been equally large; for of the private armories most reputed for early improvements one is stated at this time to have had but a single milling-machine, and that a rude one; and at another armory a single gang-saw profiling-machine was the principal stocking machine in use. It was some fifteen years later before the manufacture of milling, edging, and other important gun machinery was conducted on a scale sufficiently extensive for the general outfitting of large armories.

In the present manufacture of the finest revolvers (of .44 or .45 caliber), under favorable conditions upward of 250 may be produced per annum per operative, the operative labor being divided among the several departments

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in proportions roundly expressed in the following percentages: Forging, 12 per cent.; machining, 50 per cent.; filing, 10 per cent.; polishing, 12 per cent.; assembling, inspection, and proof, 11 per cent.; sundry processes, 5 per cent. In the best practice the workmanship is much finer than that attained in 1870, but there is in the manufacture a considerable variation in the size and quality of the pistols produced; so that a large proportionate output may be indicative of less nicety in the inspection and finish, rather than of the most approved facilities. In the past, no basis of comparison is afforded prior to the advent of the inventor, Colt, who did not establish his pistol works at Hartford until 1848. In 1854 his factory at Vauxhall, London, with 200 hands, turned out 100 pistols a day, or 156 per operative per annum; and although, both in America and in England, he then used ingenious machinery in the whole manufacture, there is no doubt but that, taking quality into account, the introduction of improved designs, speeding, and system in the mechanical work has since more than doubled the productive efficiency.

It may be said that the manufacture of double-barreled shot-guns is usually conducted under less effective conditions, besides involving more labor per arm than that of military rifles; so that a numerical output of from one-half to one-fourth as great per operative is not unusual, while barrel-making, filing, and ornamental work employ larger relative proportions of the labor.

Relative to the skill required in the manufacture, it may be said that, since most of the work is special and done by the piece, few of the operatives may, in any case, be placed under the schedule caption of ordinary laborers. The foremen upon the several jobs or sub-contracts (who may be usually rated at 1 foreman to 30 or 40 operatives), the blacksmiths and the machinists proper, the tool-makers and the barrel-straighteners, are considered skilled workmen, but the machine-tenders and other operatives, however proficient in their special duties, are not so considered. The skilled men thus specified will generally constitute less than 20 per cent. of all. But in many factories much of the machinery is tended by experienced men, drawing the wages of skilled workmen, and the employment of unskilled labor, often adduced as an advantage due to improved machinery and the interchangeable system, seems largely available only on heavy contracts, when it may be utilized with a careful system of oversight. Machinery may contract the province of certain skilled trades whose identity is as firmly established as that of the three learned professions, but the fact remains that the increased fineness and accuracy required in the manufacture of fire-arms demands the most skillful and experienced oversight, and unskilled labor can only be employed with the best results upon limited portions of the work. Thus we will find that at most of the larger armories the greater proportion of the operatives draw the wages of skilled men.

Some details of the subject thus outlined may now be supplied by a consideration (with comparisons with past practice) of the methods employed, the power and the machinery required, and the productive efficiency obtainable in the various departments of the work.

THE MANUFACTURE OF GUN-BARRELS.

DRILLING.—Barrels for military guns are now commonly made from 2-inch round steel, which is cut off into lengths of about 9 inches, in which, after centering, a ¾-inch hole is drilled. The cutting off and centering are operations involving little time or labor, the latter being done by a tool in the head-stock of a lathe, while the mold-blank is rested in ways. The drill is sometimes pressed down by a weighted spindle in a machine similar to that shown in the illustration (Fig. 1), a four-spindle machine, designed by Frederick W. Howe for Robbins & Lawrence, at Windsor, Vermont, in 1852, and then applied to the full-length drilling of steel barrels, in which work one man could tend two or more machines, and each spindle would drill 5 barrels a day, the barrels being ½-inch bore and 23 inches long. Prior to this a similar four-spindle drill was made by Albert Eames for drilling the steel barrels made by Remington & Sons for Jenks' carbines (in 1846), and an illustration is given (Fig. 2) of a barrel-drill designed by E. K. Root for Colt's armory, in which the spindles were located about a center. These vertical barrel-drills superseded drilling by hand or by means of horizontal drills, which were less accurate and efficient, and in some cases quite rude, as, for example, the device (in use at Watertown,

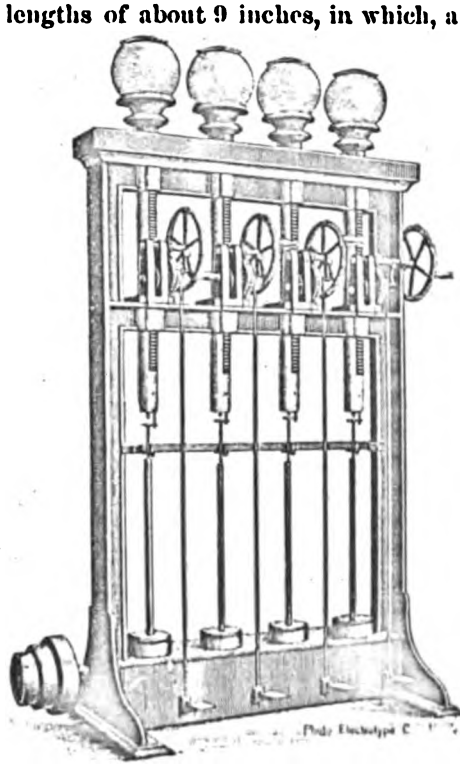

Fig. 1.

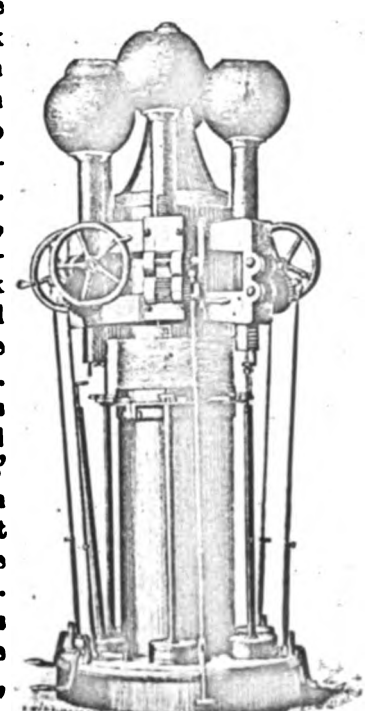

Fig. 2.

New York, in 1832) in which the barrel was rested in V-grooves in wooden blocks, and by means of hand levers was forced against drills of several successive lengths, placed in the head-stock of a lathe.

Weighted spindles may be arranged for drilling the short molds for barrel-rolling with considerable rapidity, one man tending 6 spindles, and each spindle drilling ¾-inch holes in about 50 nine-inch mold-blanks in ten hours, a weight of 450 pounds resting upon each spindle; but these vertical weighted drills, which were in the first instance designed for drilling full-length barrels, are in turn becoming superseded for drilling both molds and barrels by compact geared drilling-machines, in which greater steadiness and rapidity of drilling may be secured. Such a 5-spindle multiple drill, self-feeding, with a quick return feed, and with a drill speed of an inch a minute, will drill ¾-inch holes in about 300 nine-inch wrought-iron blanks in a day; and an illustration is shown (Fig. 3) of a special gun-blank drill (Thorne, DeHaven & Co.), with self-feeding tool, drilling at the rate of three-quarters of an inch per minute for a ¾-inch hole in steel, one boy being able to attend a battery of four or five machines.

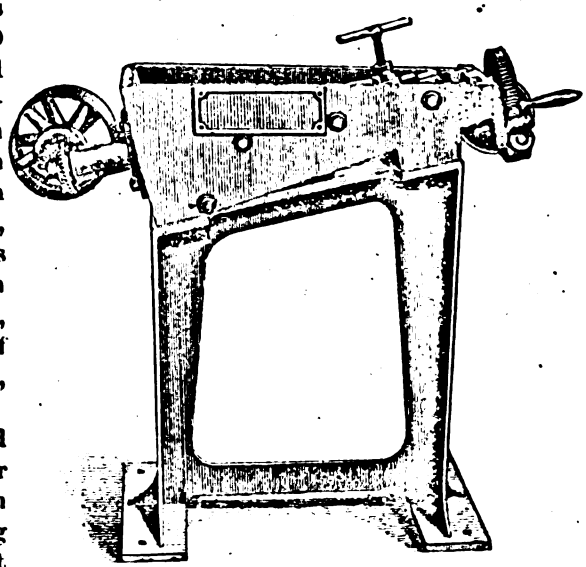

Fig. 3.

FORGING AND ROLLING.—The rolling out of decarbonized steel-molds upon mandrels occupies three men (1 foreman roller and 2 helpers) to a set of rolls, such as shown in the illustration (Fig. 4). There is more or less variation in the practice of rolling barrels, which may be generally described as follows: The first heating of the barrels requires about 8 minutes, and after each time that they are passed through the rolls over mandrels they are replaced in the furnace to maintain the heat. Sometimes two, but more generally four barrels are manipulated in one lot, passing successively through the rolls six or eight times, the first two grooves being cylindrical, and the remainder having the taper of the barrel. The alteration of form attending this operation is approximately exhibited by the sections shown in the cut (Fig. 5). Six or eight mandrels are used, reducing the bore (¾ inch) about one-half. The ends of the mandrels have knobs or enlarged, hardened bearings, upon which the barrel is pressed by the rolls. It is important to have the rods extend just to the center of the rolls, for if they go too far the hardened bearing of the mandrel will be torn off, and if not far enough the barrel will be crushed together, and the next size of mandrel cannot be introduced. The proper length of mandrel is determined by a stop, with washers upon the rod, bringing up against a bar in the frame.

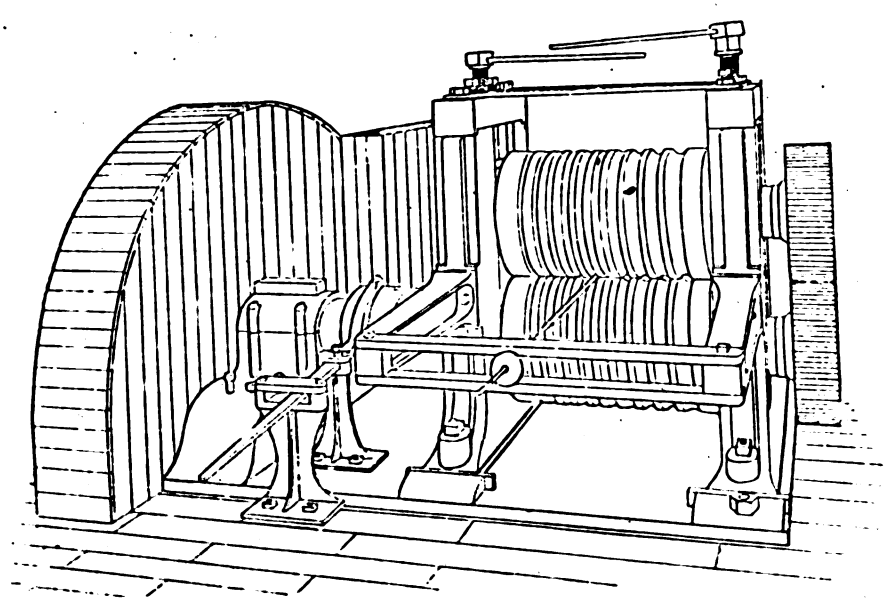

Fig. 4.

The foreman takes the mold from the furnace, slipping the mandrel into it, and thus passes it through the rolls. The first helper, standing upon the other side, receives it upon a rod and passes it to the second helper, who

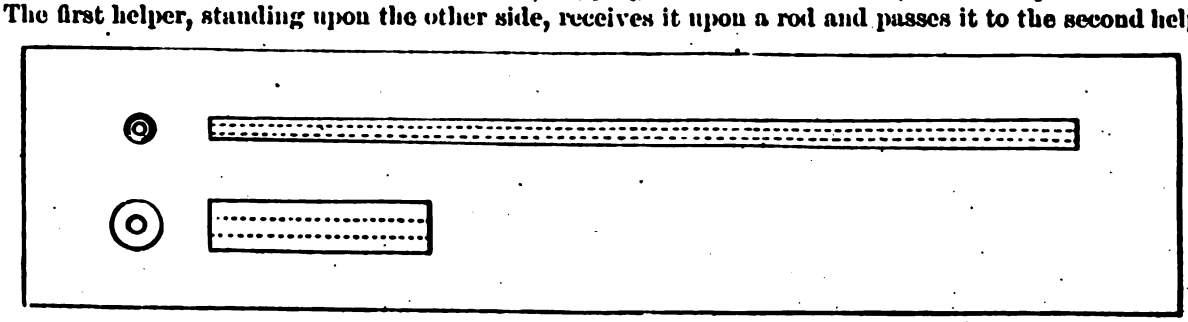

Fig. 5.

straightens it by slapping it upon a flat table, and then replaces it in the fire. After the reduction of the bore, the barrels are finally passed from three to six times through a groove of the rolls, and back over the top, without

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mandrels or reheating. The daily product of a set of rolls is about 200 for 10 hours, or at the rate of 1 barrel in 3 minutes.

Barrel-rolling was introduced at the Springfield armory in 1860 by James T. Ames, who had been sent to England, as agent of the United States government, to examine machinery for making gun-barrels and to make purchases. The method then employed in England was to roll out tubes, which were first made of skelp, bent together and welded. James H. Burton, who had been master-armorer at the Harper's Ferry armory, and who had charge of the improved machinery made by the Ames Company for the English armory at Enfield, patented a method of rolling barrels from the solid drilled tubes, the present prevailing method for military guns, which was first extensively adopted by the Remington works at Ilion, New York. Their rolls are still in charge of William Onyans, who came from England to operate the barrel machinery purchased by Mr. Ames for the Springfield armory. Prior to the use of drilled molds attempts had been made to use short, punched molds, and also steel molds cast with a core. The first barrel-rolls built in this country were made by Wood, Light & Co. for Nathan Washburn, Worcester, Massachusetts, and soon after rolls were built for the Providence Tool Company and other armories. These rolls were turned by means of a special tool, designed by Mr. Aurin Wood, for turning them with the requisite taper and jog, by means of a cam-ring, which, in revolving, forced back the tool-holder, allowing it to spring forward at the conclusion of the turn.

The fuel required in barrel-rolling depends largely upon the economical arrangement of the furnaces. As much as a net ton of coal per 100 barrels is sometimes used. At the Springfield armory, by an improved construction of the furnaces, with a method of blowing in slack, the coal per 100 barrels is reduced to as low as 500 pounds. A set of rolls, with the auxiliary mechanism, cutting-off machines, and appurtenances, appears to require about 15 horse-power. The engine is sometimes driven by waste heat from the barrel furnaces.

It ought, however, to be stated that while military barrels are, in this country, generally rolled down upon mandrels, the barrels for sporting guns are drilled full length, as is the practice at the Winchester armory and at Colt's armory. It is also significant that at Enfield the English method of barrel-rolling, so generally introduced into this country, and the present practice at the United States armory and other large works, has been abandoned for the former and more expensive method of drilling the barrels full length. This is also the method approved in the Prussian armories, where the barrels are drilled at high speed in double horizontal drilling-machines, using a straight, half-round bit, cut across diagonally at the lip, so as to bring one outer edge forward, and thus cut out the circumferential in advance of the central portion of the bore. In general, it may be said that barrel-rolls are more especially adapted for turning out great numbers of barrels of uniform size and taper. Apart from all considerations of quality, in sporting work it is unprofitable to have a set of rolls for every size and taper required In some armories the two methods will be found to be practiced side by side—barrel-rolling for military, and full-length drilling for sporting rifles.

Barrels were first forged by hand, but in 1817 the method of welding them under a trip-hammer was patented by Asa Waters, of Millbury, Massachusetts. The trips were geared to make 400 strokes a minute, running by water power. When barrels were welded by hand two strikers were employed—a lap of about 6 inches was welded at one heat, and 6 barrels a day was a fair day's work. When the trip-hammers were introduced, but one striker was required; from 14 to 16 barrels a day were welded, and the work was more nearly perfect. The practice of welding barrels under trip-hammers, instead of by hand, was not introduced at Harper's Ferry until 1836.

The earliest use of decarbonized steel for gun-barrels is generally credited to the Remingtons, who made steel barrels for North & Savage, of Middletown, Connecticut, and for the Ames Manufacturing Company, of Chicopee, Massachusetts, as early as 1846. It is also stated that some time about 1848 Thomas Warner, at the Whitneyville works, incurred so much loss in the skelp-welding of iron barrels that he voluntarily substituted steel-drilled barrels in his contract, making them of decarbonized steel, which was believed by him to be a novel expedient. The use of a soft cast-steel was begun at Harper's Ferry about 1849. After 1873 all small-arm barrels turned out at the national armory at Springfield were made of decarbonized steel (a barrel of which will endure twice as heavy a charge as a wrought-iron barrel), Bessemer steel being used until 1878, and afterward the Siemens-Martin steel.

The loss on barrels welded from the skelp sometimes ranged as high as from 10 per cent. to upward of 20 per cent. on account of imperfections in the wrought iron and in welding. The loss on drilled and rolled-steel barrels is only a fraction of 1 per cent., and in some large contracts has been within one-tenth of 1 per cent.

Damascus barrels are made from gun-rods, assorted, packed in bundles, rolled or forged small, and then wound, ribbon-like, upon mandrels and forged into barrels, the colors being brought out in the browning, in a twist dependent upon the arrangement of the different kinds of gun-rods.

Pistol barrels were at one time forged at the Colt works by the use of the Ryder forging engine. It comprised four dies and one shear, all operated by eccentric presses from a single shaft above the dies. The lower dies were adjustable, and a handle, with a lever, served to bring up the lower member of the cutting-off press. The dies used were 1 flat, 1 point-grooved, 1 curved, and 1 round-grooved, the barrel blank being then cut from the bar by the shears. The tending of this machine is said to have required more skillful handicraft than any other operation at the Vauxhall works. Pistol-barrel blanks are now generally drop-forged in dies with great rapidity, the

appearance of the forged blank being here illustrated (Fig. 6), and the operation being similar to the other operations of drop-forging, which will be elsewhere considered.

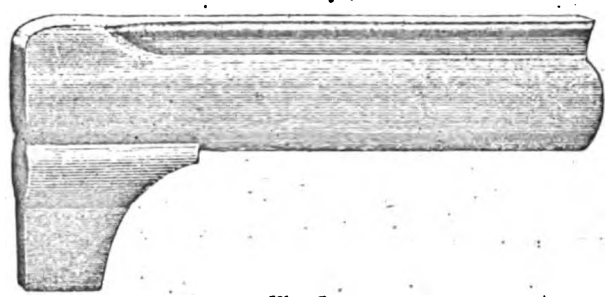

Fig. 6.

After the rolling of the gun-barrels, they are placed, while yet red-hot, in a press, whose jaws (with formers) gently reciprocate as the barrels are turned by a workman with tongs, or revolved by other appliances. This occupies two or three minutes, when they are laid out upon grooved plates, and, after a partial cooling, are cut to length with a cutting-off saw. The cutting off sometimes precedes the machine straightening, and, after annealing, another straightening is necessary, which is done under hammers.

BORING.—The first boring, commonly called nut-boring, or slow-boring, is done with a twisted bit, with a rod in tension, which tends to keep it straight. There is some variation in practice, drilled requiring less boring than skelp-welded barrels, clear water having been formerly employed where soda water is now used, and the number, time, and depth of the cuts being more or less varied. Sometimes three cuts are taken on rolled barrels, occupying 20 to 25 minutes each—about 8 barrels per day to a spindle, one boy tending a number of machines. Sometimes only two cuts are made, enlarging the bore about one-twentieth of an inch each. In past practice in nut-boring skelp-welded barrels a single cut was made with a twisted bit having a square lip, taking out about one-sixteenth of an inch. The four-spindle machine commonly in use is similar to that designed by F. W. Howe, at Windsor, Vermont, about 1850; but horizontal automatic-feed barrel-boring machines were in use at Whitneyville prior to 1840, and hand-traverse machines were generally used at an early date. It is stated that an improved nut-boring machine and auger was introduced at Harper's Ferry by James Green in 1817.

The general features of the present machines are exhibited in the illustration (Fig. 7) of a machine used at the Springfield armory, the cutter-rods being slid through the barrels before the rods are fastened in the revolving heads, and the barrels being copiously supplied with soda water as they are drawn over the cutters by the carriage, which has a rack and pinion movement.

TURNING.—Gun-barrels, not being cylindrical, are turned to formers in special lathes. In turning the barrel it has in recent years been customary to support it at the middle as well as at the ends, in order to get the turning more perfectly concentric with the bore. The use of lead center-bearings was introduced at the works of the Providence Tool Company in 1861, and a few years later Babbitt metal center-bearings were used at the Springfield armory. The barrels are placed vertically in racks, and the Babbitt rings are cast about them midway between the two ends. The barrel is then placed in a lathe, while the ring is turned smooth by two tools, successively operating, but held by a single holder—a principle of following tools which, it may be remarked in general, seems destined to be an important future factor in securing increased rapidity of machine-work. The bearing for the Babbitt ring is taken by a center rest, a circular-sector slide-ring moving in ways about the center, so that three pins, moving in curved slots and inclining toward the center, serve to push in three radial jaws, that take the bearing. The barrel is turned up to the Babbitt ring, and the jaws take a new bearing on the turned part, and (the ring being knocked off) serve to true the turning on the remaining portion of the barrel. The English practice is to use sulphur rings. In less accurate work the precaution and the expense of a center bearing would be omitted.

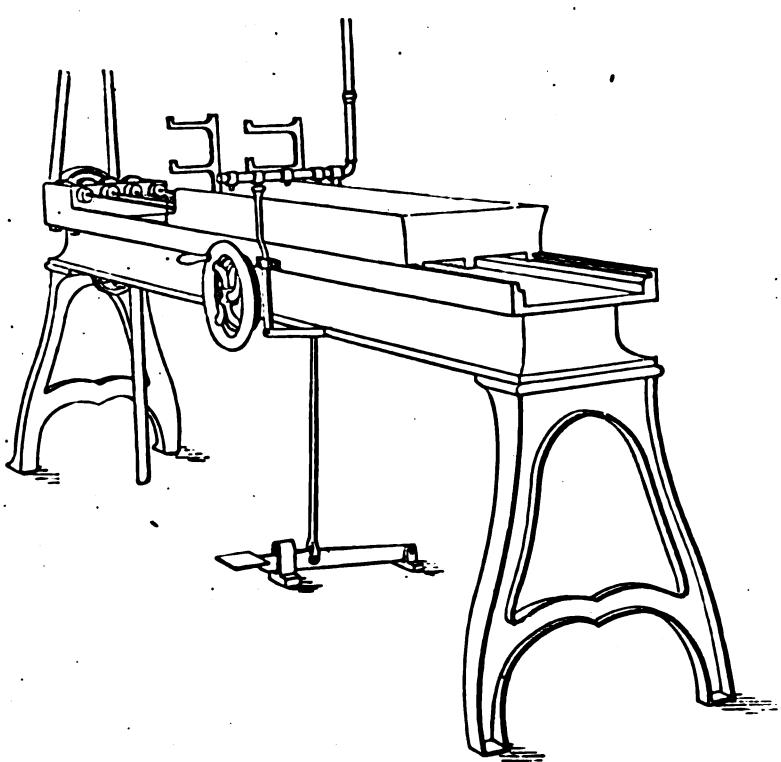

Fig. 7.

At an early date turning superseded the grinding of barrels—an operation liable to leave them with weak places where the bore was eccentric with the exterior. As compared with turning, grinding was also vastly more slow and inefficient in a ratio dependent upon the closeness of the forging. In 1818 Asa Waters took out a patent for turning barrels in a lathe, but the progress of improvement was slow, even slide and back rests not being in general machine-shop use as late as 1832. Turning superseded the grinding of barrels at Harper's Ferry about 1825. The operation

of grinding is now reduced from a principal to an auxiliary one, the barrels being surfaced, after turning, upon large grindstones. To guide the grinder more accurately in his work, a portion at the muzzle of the barrel is sometimes milled or turned to the taper.

PROVING.—In proving the barrels they are set in a frame, so that a large number are discharged at a time by the action of one hammer outside the proof-house. They are loaded with heavy charges of powder and solid slugs of lead, which are fired into a sand-bank, which may be conveniently formed within an old boiler. Although only a small percentage (for decarbonized steel barrels about one-sixth of 1 per cent.) is burst in the proving, in the long run the heavy timbers of the proof-house become well scarred with the marks of these violent explosions.

TRUING OR STRAIGHTENING.—The straightening of gun-barrels remains a skilled craft, in which mechanical contrivances have not yet superseded hand labor. The straightening is done by shade, the workman looking through the barrel at a horizontal line in a framed glass or upon a window-pane, and the lines of reflection in the bore showing any deviation from straightness. This method superseded straightening by the string or silk cord, which was in use long after the introduction of truing by shade, and sometimes at the same time and place, since truing by shade requires a knack which some find it difficult to acquire. Truing by shade is said to have been practiced by Eli Whitney at an early date; to have been introduced at North's factory, Middletown, Connecticut, by an English workman named Peter Ashton in 1830, and at the Springfield armory and at Waters' factory, at Millbury, Massachusetts, by an English workman named Thomas Smith, and to have been introduced at Harper's Ferry about 1822. It is also stated to have been introduced at Harper's Ferry by Smith after he had left Millbury. These statements seem conflicting, but the earliest practical introduction of the method as a skilled craft was probably in 1830, by Smith, whose skill was so great that at a time when journeymen's wages were commonly $1 a day he was paid by the gun-barrel, and received $21 a day for himself and boy. His blows upon a twisted barrel (to quote Mr. A. H. Waters) followed each other like the taps of a woodpecker, leaving scarcely a square without the marks of his copper hammer. He was not long left to enjoy this profitable monopoly, as his method was watched and copied, first by Thomas Warner, who afterward became master-armorer at Springfield. In 1832, at Watertown, New York, barrels were still straightened by the use of the bow and the silk cord.

In straightening, the place of the deviation must not only be seen, but the barrel must be properly laid upon the anvil and struck at exactly the right place, or else the blow causes a new bend, instead of rectifying the former one. Straightening usually accompanies smooth-boring, and is done by the same man while the boring is in progress. At this work 40 or 50 barrels a day are considered a fair day's work. On large orders men are sometimes employed to devote themselves entirely to straightening. A specially skillful operative has been known to straighten 124 barrels in a day, keeping two men busy smooth-boring; but this was an unusual rate, some men not being able to straighten more than 30 or 40 in a day. Straightening becomes more difficult with the small-bore barrels of the present day than with the larger bores formerly used.

REAMING AND POLISHING.—The quick-reaming and the smooth-boring of barrels are done with squared cutting rods or bits—augers of rectangular section, one or two of the corners being sharpened, and these reamers being backed by strips of wood and oiled paper. In this work the barrels are passed to and fro over the rods several times, and the depth of the cut is extended from time to time. As an example of former practice, smooth-boring was done in two successive operations, taking off about one-hundredth of an inch at each. It is now done in from three to five operations, taking out from two to five thousandths of an inch at an operation. The machinery used is simple, consisting of power-turning heads for carrying the rods, and carriages, with a rapid traverse, for moving the barrels back and forth. The chip cut is exceedingly fine, like powdered plumbago; and if a gauge-plug be slipped into a smooth-bore thus finished, the joint, although free, is air-tight, so that if the other end of the barrel be closed the plug rests mobile upon a spring or cushion of air, and upon the inversion of the barrel will not fall, being sustained by the atmospheric pressure.

The draw-polishing of barrels is usually performed on a 5-fold barrel-polishing machine. In this machine wooden jaws, fed with a paste of emery and oil, are pressed against the barrels, which are held vertically, and are revolved by a square spindle, passing through one of a set of geared pinions carried with the barrels by a reciprocating frame, the bearing of the spindle (which, through the pinions, gives a rotary motion to the barrels) being in the fixed frame. The operation being a brief one, a man tending two 5-fold machines can perform this work on a great number of barrels in a day. A ring at the breech end of the barrel is first polished on a buff wheel, the barrel being held by this end in the draw-polishing machine.

RIFLING.—Two methods of rifling gun-barrels are now employed—floating-cut or file-tool rifling and hook rifling. An illustration is given (Fig. 8) of a rifling-machine for short barrels operated by the former method, made by the Pratt & Whitney Company, which will serve to illustrate the general character of rifling-machines. The cross-head of the connecting rod carries a rack with a pin, which, moving in a vertical adjustable slide, serves to actuate a small gear and turn the barrel. A rod attached to the cross-head at the back of the machine actuates the mechanism for setting forward the cutters, so that they will act in new grooves, and also serves to expand them in the following manner: The cutters are in the faces of small oblong plates, so set with flat springs in a tubular rod that, an inner rod being gradually shoved forward, pushes them out and deepens the cut. At each stroke the end of the inner rod touches a plate, which is very slowly fed forward by click and ratchet work, and thus the cutters are expanded.

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The machines in use at the Springfield armory are of different design, and a chain-feed has been substituted for the crank-feed, which change in these machines, by avoiding the inertia due to a crank movement, is stated to have effected a large saving in the wear and tear of rifling rods and tools. In other factories, however, the traverse by the crank movement is preferred to that by the chain (the machinery for which was first designed by H. B. Bigelow, and introduced at Whitneyville, where it has now been discarded), and the movement is most commonly effected by the use of horizontal screws, or by ropes or bands, whose continuity of movement prevents shocks in the transmission of the power.

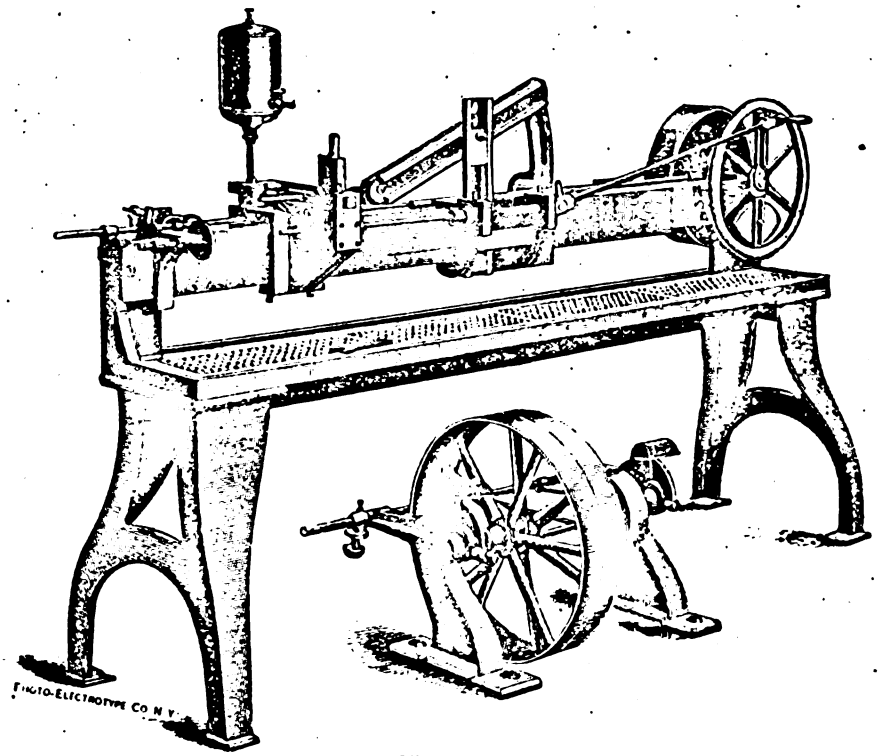

Fig. 8.

In file-tool rifling one man can tend eight to twelve machines, and from twenty to thirty minutes are required for rifling a gun-barrel. The cutter-rod is turned after each cut, so as to secure uniformity by bringing every cutter successively in every groove. The expanding cutters, as now used at the United States armory, are not applied to effect a gradual deepening of the groove from muzzle to breech, but simply to feed out the cutters gradually in making grooves of uniform depth. The chip is a very fine one, and, by a device employed at the United States armory, at the conclusion of the cut the cutters are allowed to traverse the grooves a number of times without advancing in depth, which serves to polish out the grooves, which would otherwise have to be polished in a separate machine. In file-tool rifling it is claimed that there is less liability to variation than in hook rifling, the tool being stiffly supported, and the gradually increased deepening of the cut being so much smaller that any possible variation in the hardness of the barrels is not likely to deviate or dull the tool. This method is considered the better of the two at the United States armory at Springfield. It is also the method employed in the Prussian armories.

Hook rifling was the English method, and was introduced, with some improvements, by E. Remington & Sons, at Ilion, about 1861. In this there is a regular planing cut, and barrels can be rifled in five or ten minutes, one man tending two or three machines. Perhaps it is sufficient commendation of this method to say that the Remington Creedmoor rifles are machined in this way, and that it is the method in most general use in this country, although some armories employ the other method, and some use both methods. It has also been applied in cutting expanding grooves. The hook lies back against a wedge, and the deepening is effected by a rod striking against a pin, which is slowly fed forward by a screw and wheel with a click. The hook is thus pushed out, and at each return a finger, actuated by a spring, shoves it back, so that it will not scratch the barrel in returning. The barrel is turned by a gear moved by a rack with a pin in a straight horizontal slide, and is fed forward and back by a large screw. The setting forward to a new groove is a dependent movement, effected by a weighted vertical rack, notched wheel, and click.

The earliest rifling-machines had wood frames, and the twist was obtained by the passage of a twisted rod of square section through a square hole. Such machines were used by Hall at Harper's Ferry, and in 1832 or 1833 he introduced power rifling-machines. Tryon, of Philadelphia, had power rifling-machines built prior to 1840. William Ball, of Chicopee, designed improved rifling-machines for the Whitneyville armory about 1842. These were run with oval pulleys, to equalize the crank motion. Ball's machines used only one cutter. Rifling-machines, cutting three grooves simultaneously, with expanding cutters, operated by a central cone in a tubular rod, are stated to have been first used in 1853 at Frankford arsenal, Philadelphia, Pennsylvania. In 1854 a rifling-machine was designed by H. D. Stone, at Windsor, Vermont, for the English government, which cut three grooves at a time, the twist being given by a vertical rack, actuated by a roller moving in guides. This was afterward used for the Springfield model of 1861, with expanding cutters for cutting grooves deep near the breech and shallow at the muzzle, which was done by a telescopic rod, the cutters being carried by a tubular rod and bearing against the inside rod, and being pushed out by it as the barrels were drawn over them, the cut starting from the muzzle of the barrel. Robbins & Lawrence made 2,300 stand of muskets in 1855, for the use of the English government in the Crimean war, with rifled barrels 42 inches long, rifling having been previously attempted only on barrels 33 inches long. In 1861 machines for rifling

two barrels at a time were built by Bement & Dougherty for the Providence Tool Company. In these the outp per operative was increased by greater facility in handling and placing the barrels, the rifling being with the hoo tool.

In leading or polishing-out rifle grooves a fourfold vertical machine is commonly used, the tools, which a set in rods, having a vertical reciprocating movement from a crank above, while they are free to turn, simp following the groove.

TERMINAL CUTS.—Of the remaining cuts upon the barrel there is more or less variation, according to the loc system employed. The most general of these operations are squaring, breech-turning and filing, muzzle-turning a filing, chambering, counterboring for cartridge head, milling and slotting for cartridge extractor, threading breec screw, and milling, drilling, and tapping for front and rear sights. All such operations, which might be class together as terminal cuts, probably require from one-third to one-fourth of the labor upon the barrel. The breec screw is considered to be the last gun part made uniform and interchangeable. This was accomplished in 1853 Frankford arsenal, where, according to Colonel P. V. Hagner, a method of threading breech-screws and tappi barrels by machinery was introduced, which produced identical screws. It was also done independently at t Springfield armory, where Cyrus Buckland devised a machine for starting the thread at the same point in scr and nut, breech-screws having before this been fitted by hand to each barrel.

REVIEW OF PROCESSES.—In the operation of browning, power-brush and carding wheels are used in cleani and surfacing the barrel. At the United States armory the barrel is inspected after the rolling, nut-boring, slo boring, finish-turning, finish-reaming, milling to taper, grinding, and proving after the rifling, lathe-filing of muz and rounding of muzzle-end, after the emery-finishing, and after the browning. The operations are, besid browning (which, with the repetitions, constitutes about 30 processes), cutting off, centering, drilling, rolling, sawi straightening in press, annealing, straightening on anvil, nut-boring twice, slow-boring (with squared bit), milli ends, turning for dog or holder, casting center-bearing, turning center-bearing, turning former half, turning lat half, straightening by shade, finish-turning, reboring (with squared bit), milling to taper, grinding, proving tw and stamping, rough-filing muzzle, smooth-milling breech end, seating front sight, brazing sight, milling front e of sight, filing about sight, smooth-milling muzzle end, reaming, finish-reaming, polishing breech end, draw-polishi rifling, lathe-filing muzzle, hand-filing muzzle, jig-filing front sight, rounding muzzle end, milling to length, turni screw blank, turning blank tenon, squaring shoulder, stamping center-mark, threading breech-screw, drilling ho for sight-base screws, counter-sinking for cartridge head, hand-reaming chamber, profiling for breech-block hin slotting for extractor, tapping holes for sight-base screws, draw filing, and finishing with emery cloth.

MACHINES REQUIRED.—The kinds of machines used are, in general, cutting-off lathes, centering machi barrel-drilling machines, barrel rolls, iron-sawing machines, straightening presses, drop-hammers, nut-boring a reaming machines, barrel lathes, grindstones, buff wheels, draw-polishing, rifling, and breech-threading machi drill presses, tapping lathes, profiling- and milling-machines, and common turning lathes. In a set for barr drilled full length the cutting-off, rolling, and iron-sawing machines and straightening presses would be omitt In the usual practice, leading or groove-polishing machines would be required. The number of machines requi would be dependent not only upon the output, but upon the manner of handling. Probably an output of 50 barr (drilled full length) per day would require 30 to 35 machines, exclusive of power motors, and requiring about horse-power and 25 to 30 operatives. Probably an output of 200 barrels (rolled from the drilled molds) a day co be obtained with 80 to 90 machines, exclusive of motors, requiring about 75 horse-power and 50 to 60 operatives.

MAKING PISTOL BARRELS.—The work on pistol barrels involves only such special features in machinery result from the short length and easy handling of the barrels. Improvements in detail have been made u some of the machines used by Colonel Colt twenty or thirty years ago, although these were very ingenious a effective. In the Colt barrel-drilling machine the barrel is clamped by screws in a hollow-turning arbor. T drill-carriage is held in position by an eccentric clamp below the bed of the machine. The drill is fed forward b hand-wheel, with a screw working in a half-nut, which, supported by a hinged leg with a roller and handle, may tripped up and dropped out of bearing with the screw, so as to allow the tool a quick, sliding return. Probal other forms of drilling machines now in use do more effective work. In the Colt barrel-boring machine the barr are clamped in notched bars on a traversing carriage, and are thus drawn over helical cutters upon revolving rods tension; the reaming-machines being similar, except that the bit is a square section reamer, with two cutting edg Pistol-barrel rifling-machines exhibit the same essential features as those for gun-barrels. In the Colt machine t barrels are held in hollow axles, with notched disks, operated by puppet bolts and shifting rods for moving them a holding them in position for the cutting of the several grooves. The rifling stems move horizontally in a carri sliding in ways, and moved by a crank and connecting rod from the main shaft, and are carried by spindles w spur wheels, which are turned to make the spiral groove by a rack actuated by a link or connecting rod, one end which is pivoted to a projecting arm of the frame, while the other, moving with the carriage, actuates the ra Floating-out cutters are used, which are expanded in the usual manner, a disengaging gear operating to stop machine when the full depth is cut.

Of the pistol-barrel rifling-machines designed by Howe, at Windsor, in 1853, one machine would rifle 100 pi barrels in a day.

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THE MANUFACTURE OF GUN-STOCKS.

OPERATIONS IN STOCKING.—The stock of a gun is sometimes in a single piece, and sometimes (depending upon the breech mechanism and design) in two parts, the tip-stock and the butt-stock. Beneath the latter there is sometimes added a projecting piece, called the pistol-grip. If the stock is in a single piece, the upper angle of the junction of butt and tip is called the head. The operations upon a plain gun-stock for the Springfield rifle may be enumerated as follows: rough sawing; cutting off butt and tip ends; marking four points in butt end and one in tip end for fastening in turning lathe; turning tip and butt; spotting (or by means of a circular-saw gang marking places on each side of butt and tip, and several on one side of the stock between the head and tip, as a guide for additional operations); cutting barrel-groove; cutting for receiver and tang and tenon of breech screw; finish-cutting barrel-groove; squaring tenon mortise; planing sides and edges of stock to a former; sawing off butt and tip to gauge length; cutting butt-plate curve; bedding butt-plate tang; boring and tapping for butt-plate screws; bedding for lock-plate; boring for tang of sear and for bridle and sear screws; cutting recesses for main-spring bridle, tumbler, and sear spring; countersinking for head of bridle screw; bedding for guard plate; boring for guard-bow nuts and trigger-stud; cutting mortise for blade of trigger; boring holes for guard, tang, and side screws, and counterboring for side-screw washers; finish-cutting top, upper, and lower bands, and between bands, and forming shoulders for bands, and shoulders and tenon for tip; finish-turning from heel of butt to head and from head to lower band; bedding for ramrod-groove and stop and forming holes for studs; cutting recesses for the band-springs and boring holes for their tangs; boring ramrod-groove; cutting barrel-groove for receiver; cutting groove for arm of hinge-pin; boring hole for tip-screw; finishing with hand shaves, scrapers, and sand-paper, and oiling with linseed oil. These last few hand operations require about five-eighths of the labor upon the stock, all the varied and curious cuts made by machinery requiring only three-eighths, which is a very forcible exhibit of the value of labor-saving machinery. The enumeration of the foregoing operations outlines a complete system of manufacture which has, since 1820, been gradually evolved from the whittling, boring, and chiseling by hand, which then constituted the single craft of stocking.

THE BLANCHARD MACHINERY.—In 1818 the first gun-stocking machine was made by Thomas Blanchard at Millbury, Massachusetts. One of his earliest machines, built about 1822, is still at the Springfield armory, and is here illustrated (Fig. 9). It has a large wood frame of 6 to 7½ inch timbers, the pattern and the stock-holder far apart, and carried by a swinging frame, hung upon pivots nearly 8 feet above the floor. The cutter-wheel and the guide are each 18 inches in diameter, and are carried by a very heavy iron frame, which was fed forward by a small screw spindle (with a weak V-thread) at the back of the machine, the spindle pulley being driven by a small pulley, shown at the top and extreme left in the cut. This heavy frame moved on one V and one flat guide, and the reverse movement was given by a strap or a rope, wound upon a roller turned by a handle, upon the automatic disconnection of the feed screw, which was effected by the throwing out of a half nut. The cutter-wheel was turned by a belt from a large drum, and the stock and the pattern were turned by a belt from a pulley on the same shaft, the stock and pattern being geared together by a train of four spur-wheels. This machine did excellent work in rough-turning stocks,

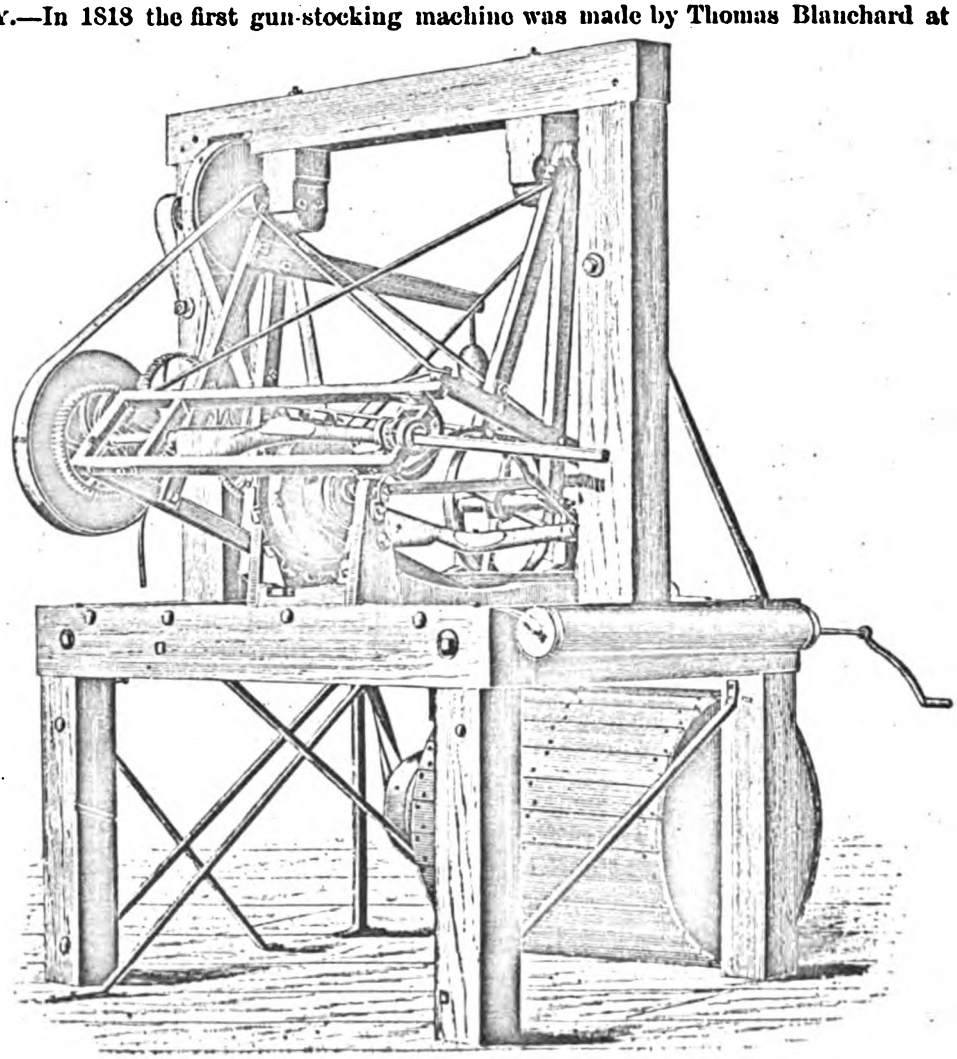

Fig. 9.

as is exemplified by samples still extant. By 1827 Blanchard's stocking and turning machinery had bee developed into 16 machines, in use at both national armories, and for the following purposes: sawing off stock facing stock and sawing lengthwise, turning stock, boring for barrel, turning barrel, milling bed for barrel-breec and pin, cutting bed for tang of breech-plate, boring holes for breech-plate screws, gauging for barrel, cutting fo tang of breech-pin, forming concave for upper band, dressing stock for and between bands, forming bed for lock plate, forming bed for interior of lock, boring side and tang-pin holes, and turning fluted oval on breech. Of mos of these machines little more than the names remain. The machine for forming the bed for the lock-plate deserve especial mention, as it indicates how far Blanchard's ingenuity in making stocking machinery had outrun th facilities for making the metal parts with which the stocks were required to fit. After the stocks were made uniform by machinery, the lock-plates and other gun parts were for some time not made uniform nor interchangeable. I was not, therefore, sufficient to cut out the stock uniformly, for the lock-plates, being of variable shapes and sizes would not fit the cut; so Blanchard devised a combination of dies sprung inward toward a center, so that the would conform inside to any shape of lock-plate set in the interior, while the outer ends formed a surface whic was used as a former, and thus every cut in wood was made by machinery to conform to the irregularities of th metal work. The use of this device, as attested by Messrs. Lord, Stillman, and others, was continued at th Springfield armory until 1840, but the machinery was destroyed, and no official record remains of this curiou invention, which was not in use at the private armories, where the lock-plates were at this time usually fitted in b hand.

Before the introduction of Blanchard's machinery one skilled man was capable of making 1 or 2 stocks in day, much of the work being in the fitting of the metal parts. With his earlier and ruder machines an output o 5 or 6 stocks per operative per day seems to have been attained at an early date. The uniformity and quality o workmanship and the number and nicety of cuts have since been gradually increased; but the machining of stock can now be done on a large scale at the rate of 28 per operative per day, and all the work, including shaving an sand-papering, which constitute the major part of it, at 10 per operative per day. For an output of 50 stocks a day 8 per operative per day for the hand-work and machining together might be stated as a practical rate. A revisio of these estimates, assisted by data furnished by Mr. A. H. Waters, is expressed in the following table:

Men per hundred stocks per day.

	Before Blanchard's improvement.	Blanchard's early results.	Present results.	Best present results.
Machine-work		10	5	
Hand-work	75	7	7	
Total	75	17	12	

STOCKING MACHINERY AT HARPER'S FERRY.—The precursor of the mill-cutter was the gang of circula saws, set together on a spindle. These were arranged so that the teeth broke joint irregularly, which prevented th splitting up of the grain of the wood. This saw-gang was used in mill-planing or profiling, the gang being place between the two sides of the slide bearings of a jig-frame, in which the rough stock was clamped, the spindle of th gang being underneath and in direction perpendicular to the slide bearings, and the jig-frame having the outlin of the profile of a gun-stock, and being moved over the slide bearings, which were on a level with the cutting edge of the gang. The saw-gangs used were from a quarter to half an inch thick and 3 to 7 inches in diameter. Th was the principal stocking-machine used at Hall's works, at Harper's Ferry, prior to the introduction of Blanchard machinery, and as late as 1844. By its use the stock was brought to a square-edged profile, top, bottom, and side but much of the work remained to be done by shaving and cutting with hand tools.

Of the other stocking machinery in use at Hall's rifle works at that time, to quote the statement of Mr. Jame H. Burton, "a circular saw 'slabbed' the face of the stock, or the surface in which the barrel was subsequentl bedded, and the surface, so faced and straightened, became the base or bearing for the subsequent operations gigging or profiling. Another circular saw—'cross-cut'—was employed to saw the ends off to the proper lengt Another machine, carrying a revolving cutter on a horizontal axis, was employed in connection with another 'gi for roughing out the groove for the barrel. Then still another machine was employed to 'spot-groove' the bed f the barrel. This machine carried a spindle (horizontal), say about the length of a barrel, the surface of which wa turned off so as to leave standing at intervals in its length of, say 3 to 4 inches, narrow belts about three-sixteenths an inch wide, which were cut with diagonal teeth of shallow depth, the spindle being in the first place turned an finished to the exact longitudinal profile and diameter of the barrel. This spindle was, of necessity, provided wit intermediate supports, to prevent it from springing when in use. The gun-stock, previously rough-grooved out for th barrel, being secured in proper position in a sliding frame, was lowered to the slowly-revolving cutter spindle unt arrested by a properly-adjusted 'stop'. The result was that the roughly-grooved bed for the barrel was 'scored' intervals of 3 or 4 inches of the exact diameter of the barrel at corresponding points in its length. These 'score

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became the guide for the hand-workman in planing out the bed for the barrel, and were the means of saving much time in fitting by hand. The gun-stock was finally rounded and shaped by hand, the draw-knife, the spoke-shave, and files being the tools employed, in connection with suitable gauges for determining the cross-sections at various points."

In 1844 J. H. King devised a bedding-machine, which was used at Harper's Ferry. In this there was a vertical drum, 2 feet in diameter, inclosed in a cylindrical frame on the same axis, the frame bearing six vertical spindles in its circumference. This frame could be moved about the central shaft and held by a spring-catch striking into notches. The drum was on the driving-shaft, and belts from it ran to pulleys on the six tool-spindles. The copying pin was set in the frame carrying these spindles. Its height was adjustable by set nuts. During action the pin remained and the tool revolved in one position. All the feed motions were obtained in the bed, which was mounted on a vertical slide, balanced on a hinge by a weight, as is a drill-press table. The bed had two horizontal slides at right angles, the slides movable by levers, and one slide being mounted upon the other. The work and the pattern, or former, were thus actuated, but the motion lacked sensitiveness on account of the weight of the bed. It was, however, an ingenious machine, and was universal so far as it served for the letting in of all the component fittings for a gun-stock; that is, the lock, guard, side-plates, band-springs, and butt-plates. Stock-turning machines were not used at Hall's works until several years later.

STOCKING MACHINERY AT MIDDLETOWN.—Stocking machinery, designed by Selah Goodrich, was in early use at Colonel North's factory at Middletown. This was used in making interchangeable stocking work for Hall's rifles, on a government order given in 1823. The stocks were made and boxed up apart from the trimmings, and required no fitting for the lock-frame parts. Of the details of this machinery little is now known, except that a machine for mill-planing to a former, now in use at the Springfield armory, is stated to be of a design derived from one of Goodrich's machines.

THE AMES MACHINERY.—The principle of cutting to pattern in irregular turning, bedding, and profiling was thus gradually put into application at all of the armories, but in many of them only to a limited extent, and with very rude and imperfect mechanism, by which the full benefits of the method were by no means obtained. Of the stocking machinery of this period few relics remain. In 1853 the Ames Manufacturing Company, of Chicopee,

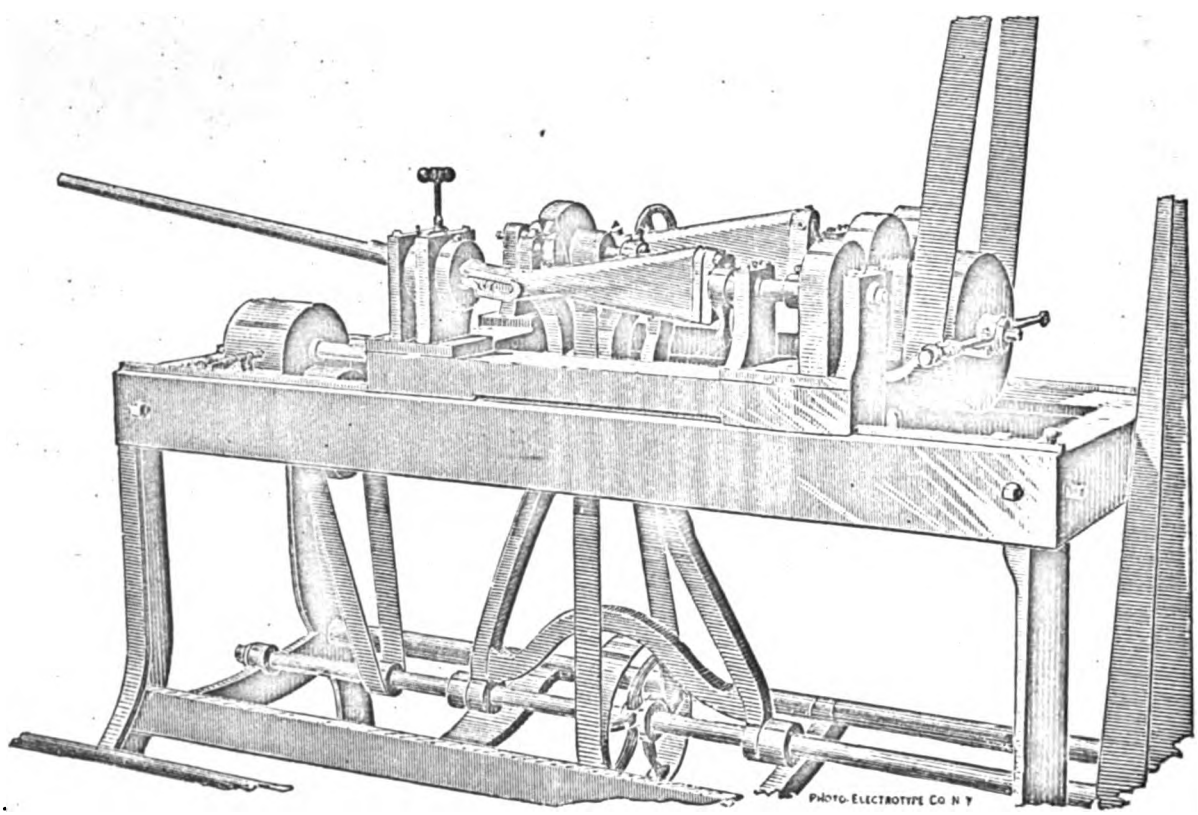

Fig. 10.

Massachusetts, commenced the manufacture of Blanchard stocking machinery from improved designs by Cyrus Buckland, which may be considered to mark a new epoch, not only in the improvement of the machinery, but of its more extended application throughout the world. The Ames machines are in use to-day both in American and in foreign armories, the earliest foreign orders coming from the British government, the British board of ordnance, the London Armory Company, the royal artillery department of Spain, the Birmingham Small-Arms Company, and the Russian government.

These early orders were for between 400 and 500 machines, beside fittings. The machines were for the most part modified designs of the Blanchard stocking machinery, but also included machinery for milling, edging, and barrel-boring, and other metal-working, and forging and proving machinery for gun parts; in fact, almost every machine then employed, from a drop-hammer to a milling or a barrel-polishing machine; dynamometers and experimental machinery for proving and testing; edging, drilling, tapping, reaming, grooving, barrel-squaring, chucking, broaching, stamping, spring-setting, and other machines, beside more or less complete sets of stocking machinery. It is to be remembered that stocking machinery is so prolific in output that a comparatively small number of machines will do the world's work.

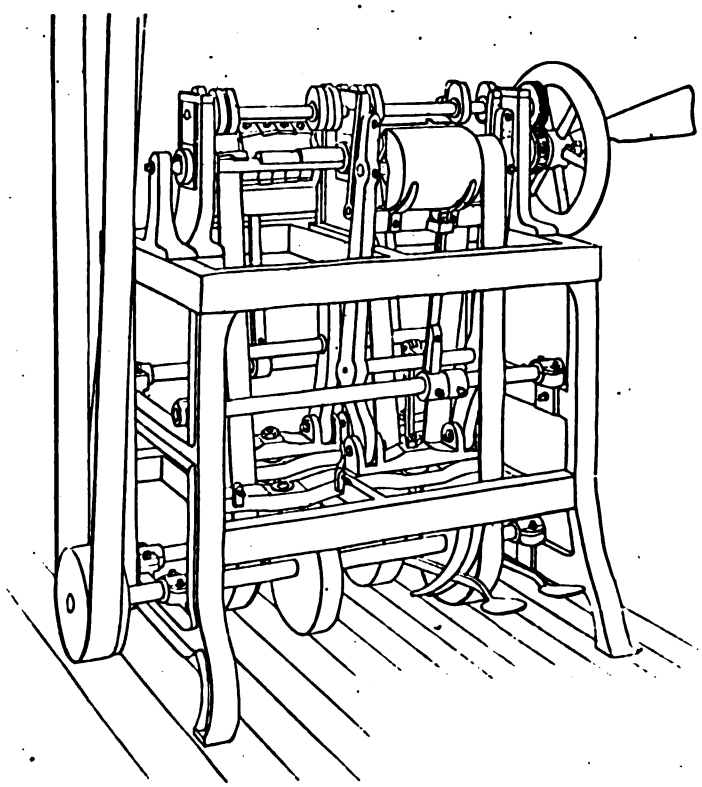

Fig. 11.

TURNING TO PATTERNS.—The illustration of the Ames butt-stock turning-machine, here introduced (Fig. 10), is naturally compared with that of the primitive Blanchard stock-turning machine. The more compact arrangement of the later machine will at once be noted. The frame is of metal. The swinging arm, carrying the guide and cutter-wheels, is pivoted below the bed on a shaft, from which the cutter-wheel is driven by a belt, the wheel being held to its work by a spring pressing against the arm. The carriage containing the pattern and stock-holder has a longitudinal movement, the gearing for turning the stock and pattern being driven by a belt from a countershaft above the machine.

In the stock-turning machine in use at the Springfield armory the stock-holder is placed above instead of by the side of the pattern, the cutter-wheel being above the guide-wheel. The traversing belt for the carriage is dispensed with, and all the motions are obtained

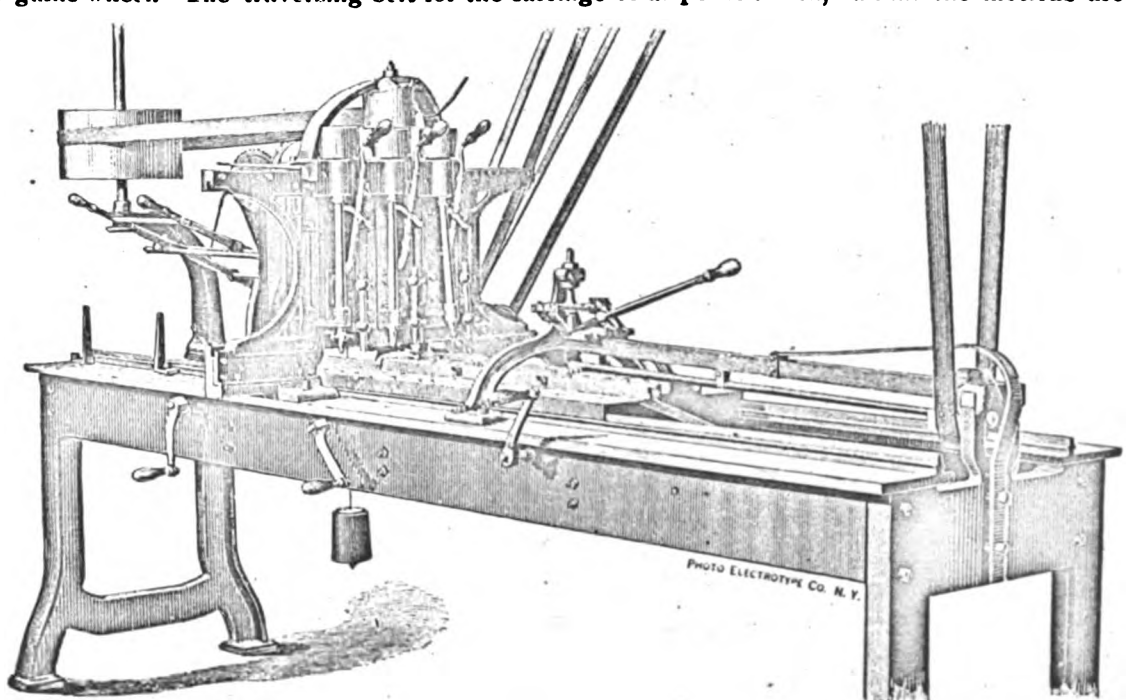

Fig. 12.

in train from the shaft beneath the bed, the traverse of the carriage being obtained through a screw and worm-wheel feed motion. Other forms of machine have the stock-holder and former driven by a long, spurred shaft admitting of longitudinal traverse, and some of the most recent designs have the stock-holder and the former side by side and the carriage driven direct from a countershaft, but the guide and cutter-wheels, instead of being mounted on a swinging arm and held to the work by springs or weights, are mounted on a transverse slide carriage, moving in ways and actuated by a weight.

The machine for turning between bands, as used at the Springfield armory, is shown in the illustration (Fig. 11). The cutter-wheels are carried by swinging frames, and the form is given by guide-plates striking against former-cams upon a spindle. This machine has a hand-feed and motion for the stock and the cam-shaft.

MILLING TO PATTERNS.—For mill-planing to a former the machine used has a milling-cutter and a guide-wheel on one vertical spindle actuated by power, the jig-frame former and the stock-clamp being upon a long arm or lever resting upon a plate. This arm is pivoted in a horizontal slide and operated by hand, so as to bring the former against the guide-wheel, while the cutter mills the stock to the same form.

BEDDING AND DRILLING MACHINERY.—An illustration is here given (Fig. 12) of the Ames barrel-bedding machine. The machine now used at the Springfield armory differs from it only in having one additional vertical spindle. It may best be described in a review of the operations of barrel-bedding. The first operation is the cutting of the barrel-groove. The stock is fixed upon the carriage beside the former-plate containing the slots and shapes, which, by regulating the movements of guide-pins, determine the cuts upon the stock. The row of vertical cutter-spindles, each with a pulley at the top and a guide-pin beside the cutter, is carried by a slide-frame with a transverse movement, so that the pulleys may be successively driven from one standing belt, and the cutters may be successively brought into position for the work. The spindle of the barrel-grooving cutter is lowered by its handle; its guide-pin enters a slot in the former-plate, and as the carriage is moved along the bed (by a crank and gearing) the cutter, by two cuts, forms in the stock a double groove. Two cuts are necessitated by the taper of the barrel, and a ridge is left between them at the center base of the bed. This ridge, prior to 1849, was planed out by a properly-rounded hand-shave or planer. Cutting the sides of the groove for the receiver, and cutting the mortise for the tenon of the breech-screw, comprise the second and the third operations on the Springfield rifle-stock, each requiring a separate spindle and cutter. The fourth operation, cutting the groove for the tang of the breech-screw, is a sloping cut, which is executed by means of a tilted spindle. This tilted spindle is run by a ball-pulley, a ball, by friction against the interior of the pulley, transmitting the motion to the spindle. The fifth operation—smoothing the barrel-groove to shape and removing the ridge at the center base of the groove—formerly done by hand-planers, is now done by means of a horizontal cutter, driven by a separate belt. This cutter is carried by a long rod, and with its frame and guide-pin may, by means of a four-motion cross-head and handle, be given a motion which enables it to form the groove truly to the taper of the barrel. This labor-saving device was invented in 1849 by Mr. Stillman, of the Springfield armory. The seventh operation—squaring the end of the barrel-groove for the receiver—is also done by a horizontal cutter, which is brought down to the work by the handles of the hinged frame shown back of the vertical spindles in the illustration. This cutter is driven by a separate belt, and after the cut is made, it is allowed to be drawn up out of the cut by a weight with a chain passing over a pulley and attached to the hinged frame.

The earlier barrel-bedding machines had double rows of vertical spindles before and behind the transverse slide, and so required two standing belts. About 1842 one was built at Whitneyville having all the spindles in front of the slide and one standing belt.

Other stock-bedding and letting-in machines are similar to the barrel-bedding machine in principle, but a few additional examples may be noted. In the Ames butt-plate machine the frame bearing the vertical spindles, instead of moving on a transverse slide, is pivoted on vertical bearings and supported by rollers moving upon a plate back of the spindles. This is shown in the illustration (Fig. 13). A horizontal cutter-spindle, driven by a separate belt, is mounted upon the same frame.

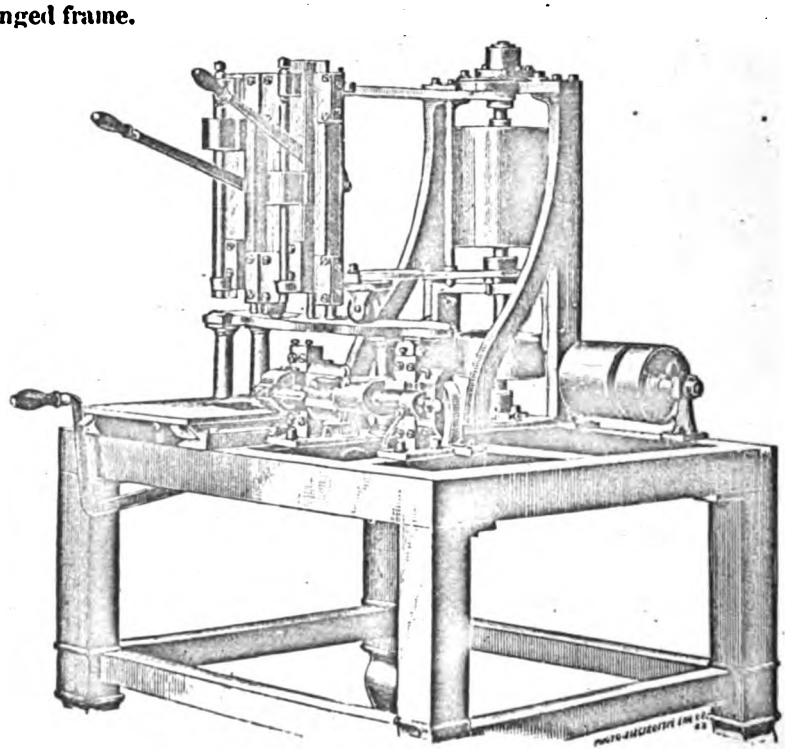

Fig. 13.

The guard-bedding machine, as used at the Springfield armory, exhibits the feature of an oscillating fixture, which has the effect of enabling the operative to tilt the barrel with precision, so that cuts perpendicular to the stock may be made in several positions. This machine, as illustrated (Fig. 14), is fitted with a fan-blower and air-pipes for the removal of sawdust. An illustration is also given (Fig. 15) of the Ames lock-plate bedding-machine, which is a machine of Buckland's design, and, with some minor exceptions, the same as used at the Springfield armory. In this machine the vertical spindles rotate about a center, stopping over the work, which is passed through the bow or yoke above the bed. The looped

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springs serving to lift the cutters back from the work, and the coiled springs and catches to regulate the chuckir movement about the center and the successive engagement of the spindles, give an appearance of complexity

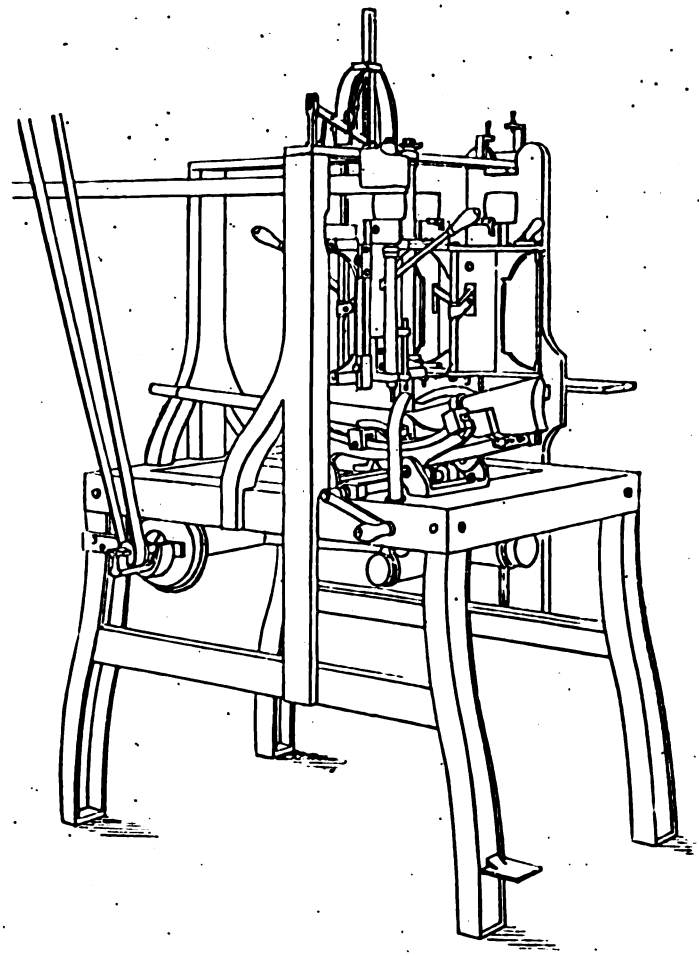

Fig. 14.

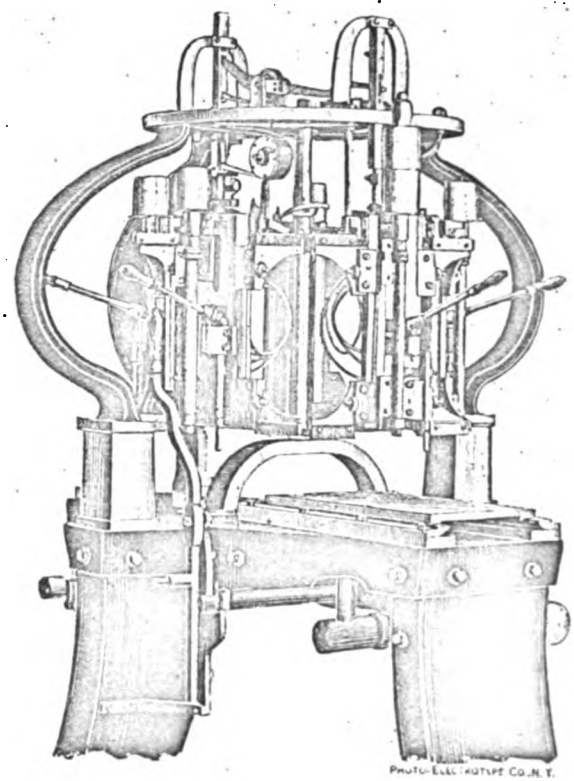

Fig. 15.

the machine. In more recent designs these ends a attained by devices less conspicuous and probab equally effective. Other bedding-machines ha tables that can be lifted and lowered, giving sco for a greater variety of work. Of the more rece improvements, the pivoted holder is perhaps t most important. Prior to the use of the tilted spindle on the barrel-bedding machine the stock was tilted accomplish the bedding of the tang, but with present devices a great number of operations can be performed in o machine upon the butt-stock, once clamped in a pivoted holder; operations such as bedding for the barrel, receiv tang, ramrod, and butt-plate, formerly requiring several machines. A similar machine is used for the tip-stock, ea machine having five vertical spindles. These pivoted holders or jig-frames, containing in themselves the gaug and formers for the various cuts and borings, as well as the stop attachments for determining the movement of t work, present examples of complex and ingenious design.

The drilling of the stock for the ramrod is sometimes a delicate operation, on account of the length of bit and t necessity for great accuracy; the hole being liable to break into other cuts if not exactly placed. The open part the cut is bedded by a mill, and the hole was formerly drilled by hand. In 1840, under Thomas Warner, at t Springfield armory, the attempt was made to drill the hole by machinery, using a ship-auger bit, which has a sing groove without core. This failed, and hand-drilling was resumed until 1860, when the precise machine meth which had failed twenty years before was made a success by a knack of manipulation in starting the bit at the rig depth. The labor upon the cut was thus reduced to one-fifth of the former labor, and the cost of the cut from cents to 5½ mills. In some armories the cut is made in a similar manner, but with a double-grooved bit.

Bedding-mills (of ⅛ inch to ¼ inch diameter) have a velocity of 5,000 to 6,000 revolutions. The power requir by stocking machinery is light. A set of stocking machinery for 250 stocks a day can be built for about $10,000, b the earlier sets, which were more complicated and experimental, cost two or three times as much.

ESTIMATE OF LABOR.—We are indebted to Mr. J. M. Clough, superintendent of the Florence Machi Company, for the following estimate of the labor required for the turning out (machining) of 250 musket-stoc per day of 10 hours, the daily attendance per machine being given in fractions of a man's time:

1 cutting-off saw bench	0½
1 profiling saw bench	0½
1 rough-profiling machine	0½
1 finish-profiling machine	0½

1 barrel-bedding machine	1
1 band-turning machine	0½
1 between-band and nose-cap turning machine	0½
1 butt-plate cutting machine	0½
2 butt-stock turners	1
1 machine for cutting butt-plate tang and boring and tapping for screws	0½
1 machine for letting in lock and guard plate	1
1 ramrod-grooving machine	0½
1 band-spring seating and boring machine	0½
1 ramrod-spring and boring machine	0½
1 ramrod-boring machine	0½
1 nose-cap boring machine	0½

This was for Springfield musket-stocks. Such an estimate would, of course, vary with the form of stock, with the hardness of the wood, with the speeding and the feed of the cutters and work, with the condition and designs of the machinery, and with the rapidity of the operatives in handling the work.

PISTOL-STOCKS.—The work upon a pistol-stock can hardly be compared with that upon a gun-stock. The pistol-stock is usually composed of two small sides of wood, hard rubber, horn, ivory, or other material, fastened upon a drop-forged iron frame. The bedding, pressing, or milling of these pieces involves no heavy item of labor, and the whole work is similar to that upon cutlery handles.

FORGING GUN COMPONENTS.

DROP-FORGING.—The forged lock parts and trimmings of a gun (pieces which are technically known as gun components), being of various shapes and sizes, are subjected to different methods of treatment in the forging. Some parts, such as the larger screws (the smaller being machined direct from the rod without forging) and flat springs, are die-forged under pony hammers, and are afterward annealed and pickled. Flat springs are also drop-forged, the forging before the fin is trimmed off appearing very much as shown in the cut (Fig. 16). Of the larger and less regularly formed parts some are dropped in dies in several operations without reheating, the first blow blocking out the material, and one or two additional blows sufficing to bring it to shape. Parts of considerable complexity of form can thus be gradually swaged out, which, by a single blow, or by the use of an unsuitable succession of dies, would only be cracked and spoiled.(a)

Fig. 16.

The rough or blocking-out dies are of cast iron, the finishing dies of steel. The accuracy of the form is proved by making a lead casting between the dies. The forgings are sometimes brought closer to form by dropping in dies and trimming and reheating before the second dropping. Parts like the bands of a barrel, having an open central space, are sometimes second-dropped upon a mandrel. The butt-plate, a curved piece requiring a weight of iron of about 12 ounces, is blocked from the rod by twice dropping in dies, is then trimmed, reheated, and redropped, annealed, pickled, and dropped cold, and the body and tang are trimmed in two operations. The pickling to remove scale is done in vitriol; the annealing in charcoal, brought to a proper heat in furnace boxes, ovens, or retorts. For softening, the smaller pieces are sometimes placed in a charcoal box in an annealing oven, the flame being carried under the box, on both sides of it and above it, and a tube passing through it revealing by its color the proper temperature for dampening the fire.

Fig. 17.

All the smaller parts are forged from rods or bars of merchant iron or steel, the butt-plate, for example, from ⅜-inch by ⅝-inch iron, the large pins and screws from round, and the springs, hammers, and other parts from square or flat steel or iron. The end of the rod or bar is heated in the fire, and the piece is blocked out in the dies upon the rod; the rod being used as a handle for the insertion of this end-piece under the several drops, and the piece not being cut from the rod until the final blow, leaving the piece, as shown in several illustrations (Figs. 17 and 18), with a fin to be sheared off in the trimming-press.

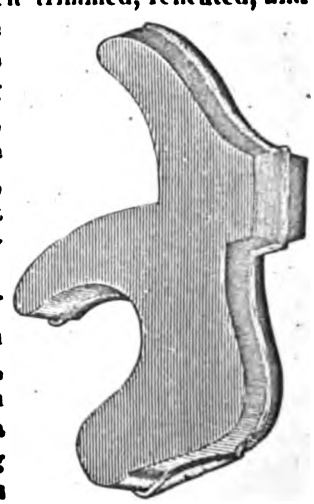

Fig. 18.

An illustration is shown (Fig. 19) of a pistol frame as made by the Billings & Spencer Company, of Hartford, Connecticut—a company which has applied die-forging to a vast variety of complicated forms in small mechanism, being pioneers in this class of work. Such a pistol frame can be drop-forged in dies at the rate of 60 an hour,

a In the unsuccessful effort to make interchangeable work in France in 1785, die-forging was tried as an important means necessary to this end, and was abandoned on account of the pieces being spoiled and cracked by improper swaging.

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involving the use of 3 pairs of dies and 3 different forging operations, beside the trimming, annealing, and pickling A pistol-hammer is drop-forged in three operations, a man and boy in attendance, in half a minute or less.

For the heaviest pieces the stock has to be worked under a trip-hammer very much as the stock for axes and hammers is worked. The frame of the Remington shot-gun is made from 2-inch square Norway iron, cut to lengths. The pieces are heated and drawn out under a hammer to form the tang, and are then forged in a steel die under a 900-pound drop.

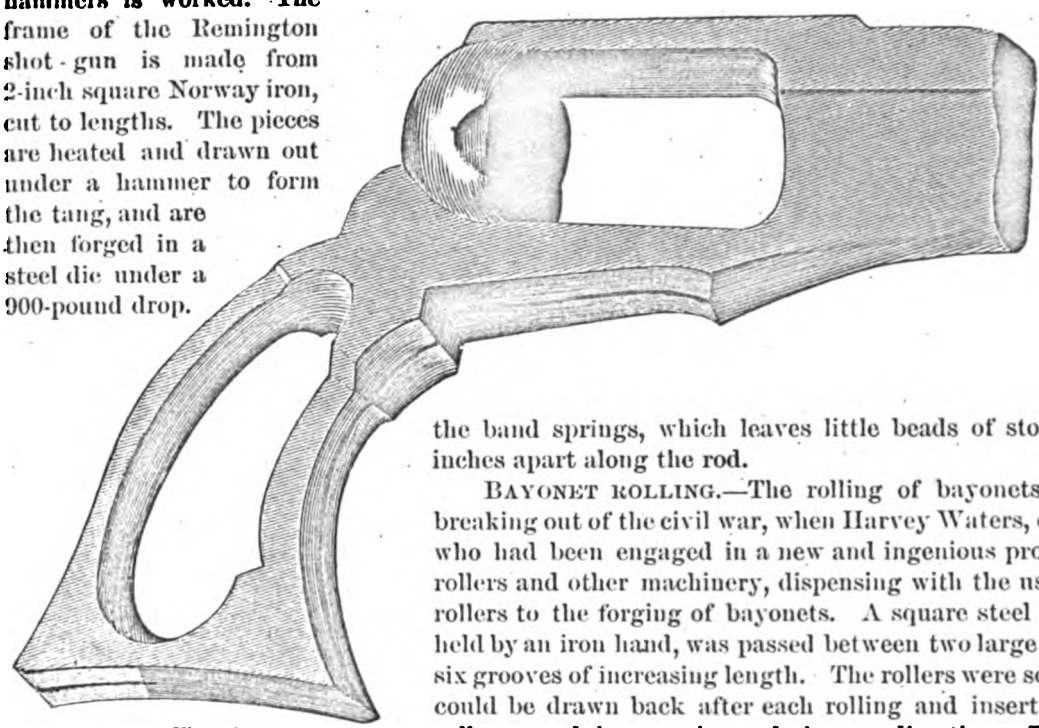

Fig. 19.

ROLLING.—The forging of stock by rolling is applied with advantage in some cases. Simple examples of this are furnished in the rolling of the metal for front sights the rod being rolled to the cross-section, and having only to be cut off in length to form the rough sight (though the sight base is formed in a die), and in the rolling of the steel for the band springs, which leaves little beads of stock at intervals of about inches apart along the rod.

BAYONET ROLLING.—The rolling of bayonets was commenced after the breaking out of the civil war, when Harvey Waters, of Millbury, Massachusetts who had been engaged in a new and ingenious process of making scythes by rollers and other machinery, dispensing with the use of trip-hammers, applied rollers to the forging of bayonets. A square steel rod was heated, and, being held by an iron hand, was passed between two large rollers successively through six grooves of increasing length. The rollers were so arranged that the bayonet could be drawn back after each rolling and inserted in the next groove, the rollers revolving continuously in one direction. This machine was not only much more efficient than the old process of forging under trip-hammers, but saved 2 ounces of steel on each blade—not only a saving of that weight of steel, but of the greater expense of milling, filing, and grinding that weight of steel from the forged bayonet. To quote Mr. A. H. Waters:

> The bayonet machine was capable of turning out at the rate of 4 a minute, but 1,500 a day was the average day's work. The price charged for rolling was 10 cents each. The rollers were 3 feet long, chilled in casting; had 6 grooves (cut in after being chilled, difficult operation, the rollers being harder than cast steel), increasing in length, the last one making the flute. The rollers were scarfed off or flattened on one side, so that the blade was released on coming to the vacancy, and could be drawn back and carried to the next groove, all the motions being automatic and timed exactly so that the iron hand did not release its hold until the whole shape was perfected.

At the Springfield armory the practice is to pass the bayonet through nine grooves, four for drawing out the stock and five for fluting the bayonet, which is passed three times through the last drawing-out groove. For each bayonet the requisite weight of stock is measured with precision upon the rod, for cutting off, by the displacement of water. The neck part is then heated and bent at right angles to the blade for the upsetting of the head, after which the socket plate is welded on under a trip-hammer, and with two heats is turned over and welded into shape upon a mandrel. The neck is finally, after heating, brought into its proper position under a die, and the annealing of the socket and the pickling complete this portion of the work upon the bayonet. Bayonets were forged by hand at the Springfield armory until about 1840, when the practice of forging them under trip-hammers was introduced.

JUMPER-DIES.—Some rough forms of dies for swaging appear to have been in use in hammer and anvil work from the earliest times; but when as late as 1842, upon pistol work at Chicopee, Albert Eames introduced die-forging with two dies and a heavy sledge—a method before commonly used in striking up lead and copper ware—its application to iron work was there regarded as novel. Such dies were called jumpers or jumper-dies.

DROP-HAMMERS.—The die-forging machines used by J. H. Hall at Harper's Ferry as early as 1827, and mentioned in *Ordnance Reports*, vol. 1, p. 155, were chain-drops. An endless chain, passing over toothed pulleys above and below was actuated by a crank on the lower pulley. A hook upon the drop (the drop moving in ways) engaged with the chain, and the weight was thus lifted to the desired height, when it was disengaged by the action of a lever and cord. It will thus be seen that in the practice of drop-forging with dies Hall was greatly in advance of his contemporaries of the north, in which section one of the earliest instances of the use of drops for die-forging furnished in the strap drop, devised by Albert Eames for the Remingtons about 1846. This drop was raised by a leather strap wound upon a cylinder. The lock drops, in which a strap was used in connection with a crank and pin, were also introduced at an early date. The compound crank-drop, designed by E. K. Root about 1850, has a high frame of four pillars, at the top of which is the driving shaft, and a crank, which actuates a vertical column moving at top and bottom in slide-bearings. Between the four pillars of the frame are four drops, the machi

being thus four-fold. On each drop are two puppet bolts actuated by flat springs. These bolts strike into notches in two sets of rods, one set moving with the reciprocating column, and the other being fixed to the pillars of the frame. By the successive operation of these bolts and the movement of the lifting column the drops climb to a height determined by a dog, which covers one of the notches, preventing the first puppet bolt from striking into it. Disengagement is effected by a sliding section of the notched rod in the frame, which, actuated by a treadle, pushes out the second puppet bolt, letting the weight fall. An illustration is given (Fig. 20) of part of the interior of the

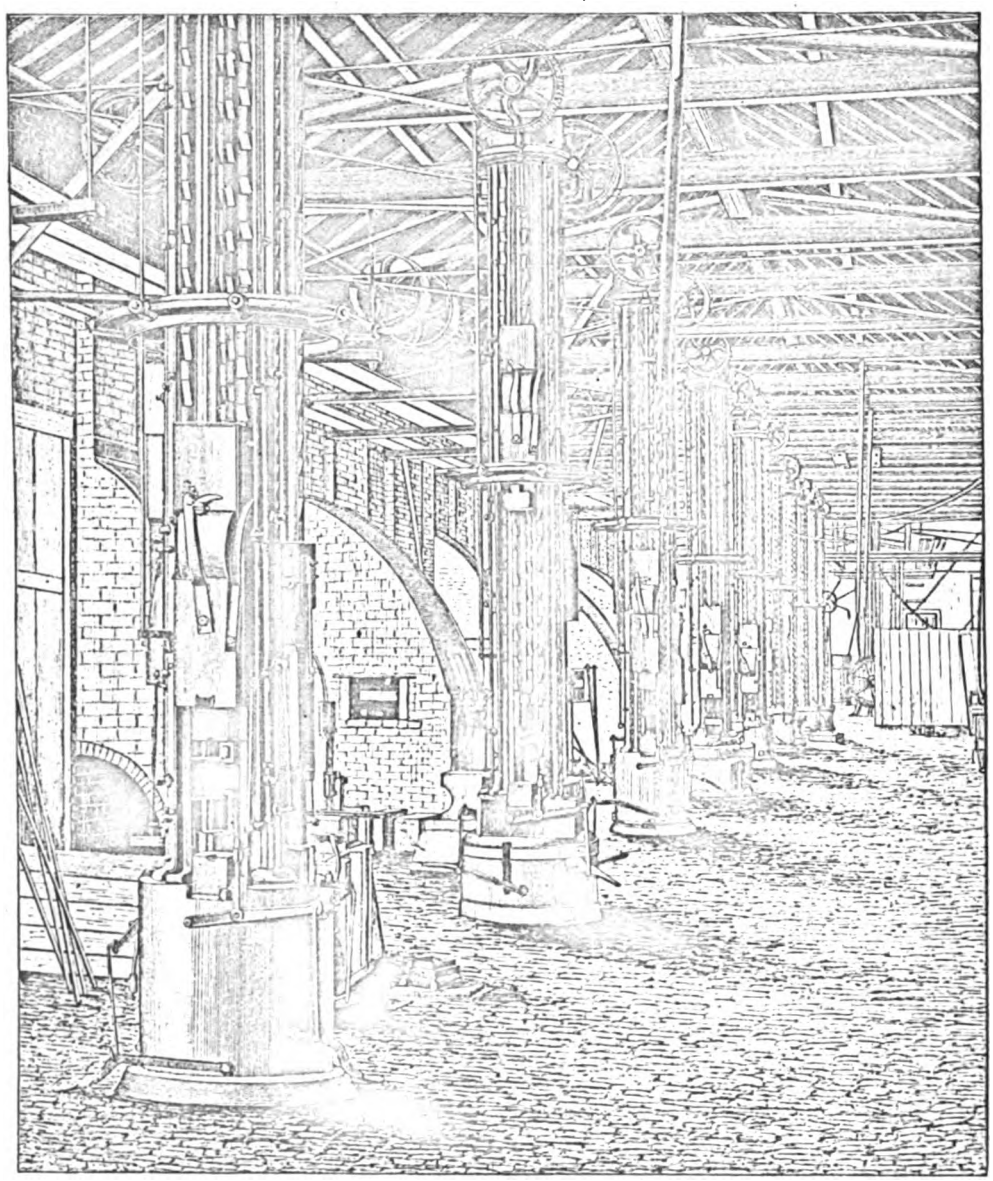

Fig. 20.

Colt drop-shop, showing a number of these machines. The compound four-fold screw-drop was also of Root's design, and was superseded at Colt's armory by the crank-drop, which was built upon a similar principle, but with more rapid action. In this screw-drop four hammers climb by means of a large vertical screw, and are stopped and detached at desired heights by the action of dogs and springs. This would forge a pistol-lock frame in two minutes. In 1861 ten drops were built by Lamson, Goodnow & Yale, of Windsor, Vermont, for die-forging at the Springfield armory, the drops previously in use there having been of a rough character. The present form of drop most generally approved for die-forging is the plank-drop, in which the weight is held by a plank of tough wood, which may be instantaneously grasped at any point by a pair of cast-iron rolls, one of which has its bearings in a movable yoke. With this arrangement the force of the blow can be instantly varied at the will of the forger. An illustration (Fig. 21) is given of such a hammer (Pratt & Whitney Co.). This machine weighs 11 net tons, the hammer weighing 1,200 pounds, and having a fall of 6½ feet.

Cold-pressing.—In 1875, at the Springfield armory, the process of cold-pressing began to be used, effecting a considerable saving in milling cuts. As an illustration of the novelty and capability of this process, the adaptation

of a large number of old bayonets to guns of smaller bore than those for which they were made may be described as accomplished at the Springfield armory. It was necessary to reduce the size of the shank nearly one-sixteenth of an inch in the diameter. This was done by pressing it, cold, upon a mandrel between two dies. The fin at the joint of the dies was very slight, the metal being simply condensed by the powerful pressure. In a gun-lock hammer of fine finish four or five milling operations are saved by cold-pressing. By cold-pressing alone, without milling, a good gun-lock hammer may be produced by the use of proper dies. The parts so produced are of superior toughness and hardness. By the use of fine steel dies they can be made much more exact than the so-called interchangeable work of early days. Other lock parts and trimmings may be similarly treated. The band is cold-pressed upon a mandrel, and would not require to be edged were it not for the slight burr left after facing. The power press used at the Springfield armory has a capacity of upward of 800 tons, having two 8 by 12 inch risers, but it is none too heavy for work which requires such a degree of condensation of cold steel. It is believed that parts thus pressed acquire properties approaching those which have been proved to exist in cold-rolled iron. Hydraulic pressure is also used in cold-pressing. Cold-pressing of elaborate forms requires expensive machinery and considerable power, and the process is as yet applied only to a limited extent. Flat pieces are often cold-dropped, which is a very rapid and simple operation.

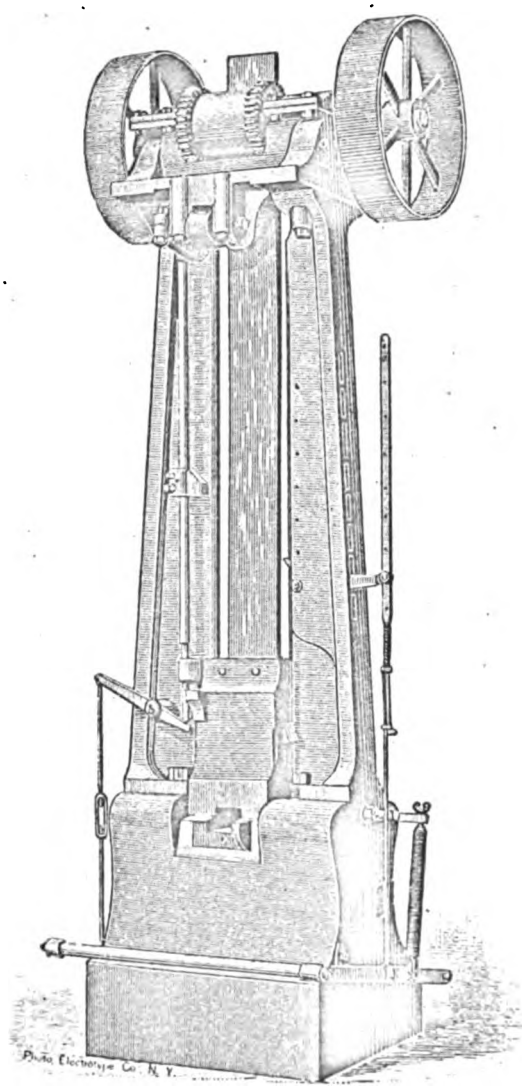

Fig. 21.

IMPROVED METHODS AT THE SPRINGFIELD ARMORY.—In reviewing the progress of gun manufacture we have seen a number of skilled crafts practically obliterated by the advent of improved machinery. But, with the growth of the processes of die-forging and pressing, the craft of die-sinking becomes of greater service and consequence. Even here, however, we find that the labor may be greatly lessened by typing—that is, by making steel types or models of the form—which is then dropped in hot steel, giving the reverse impression desired. These forms may in almost every case be more easily made than the corresponding recesses in the die-plates. A little finishing by the die-sinker will then complete the die in good shape, and it may be hardened and employed as usual. This method of economizing in a highly skilled branch of labor is in use at the Springfield armory.

In the illustration given of the plank-drop there is shown a wrought-iron die-bed secured by a key. This saves the trouble and expense of redressing the main bed in case of damage. At the Springfield armory there is employed a method of keying the die-plates themselves into a solid die-block, so that the die-plate proper may be made small and light, and the trouble and expense of using a heavy block for every die may be avoided.

MACHINE PLANT.—Exclusive of barrel-forging, the machinery required for forging the parts of between 50 and 100 guns a day might be enumerated as 5 or 6 drop and 3 or 4 pony hammers of graded sizes, 2 or 3 shear and trimming presses, a blower, a die-sinking machine, and 12 to 20 firing stands, beside tools; and a considerably larger output could be obtained without any proportionate increase in the machine plant.

MACHINING GUN COMPONENTS.

MILLING.—Of all the machines used in the manufacture of gun parts none are so numerous or so characteristic of the manufacture as milling-machines. They are applied to an infinite variety of work under a great variety of conditions, and the development of their efficiency has been due more to higher speeding, closer workmanship, and better adjustment of the weight and strength of parts than to inventions of mechanical design. Their important place may be illustrated by a few examples. Of a plant of 205 machines for turning out 50 breech-loading rifles a day, with an attendance of 175 men, over one-fourth of the machines were milling-machines. Of a plant of over 600 pieces of power machinery for turning out 400 fine revolvers a day, 28 per cent. of the machines were milling-machines. Of a gun-making plant of 850 machines, 216 were milling-machines. Of a pistol-making plant of 225 machines, hand and power, 30 per cent. were milling-machines. These figures are exclusive of edging, profiling, and other machines, on which mill-cutters are used, but refer only to milling-machines proper. Another large plant has about 30 per cent. of its total number in milling- and edging-machines. When any machine may be used

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in such numbers and for such a variety of work, it may be said, within limits, that the larger the outfit the better equipped is the establishment. In considering the efficiency of output we find that men and machines, if we may so speak, can rarely be rated as commensurate quantities. Economy in attendance is procured at the expense of economy in machinery, and, with an assured demand for the product, an idle milling-machine does not cost as much as a man, who, however industrious, is obliged to pursue his work under conditions which render him as inefficient as though he were idle a good part of the time. Every important part of a gun requires more or less milling, and upon some single pieces as many as 12 or 15 machines may be used to advantage for a large output. Although by change and arrangement of fixtures the number of milling-machines may usually be greatly reduced, yet from the fact that the machines are built by manufacturers in large numbers for the trade, while the fixtures are usually made by job work, after special designs, the cost of the fixtures not infrequently exceeds the cost of the machines.

An illustration is here introduced (Fig. 22) of an interior view in one of the Colt's armory shops, showing how the machinery is massed together in such works. In this cut several horizontal slotting-machines occupy the

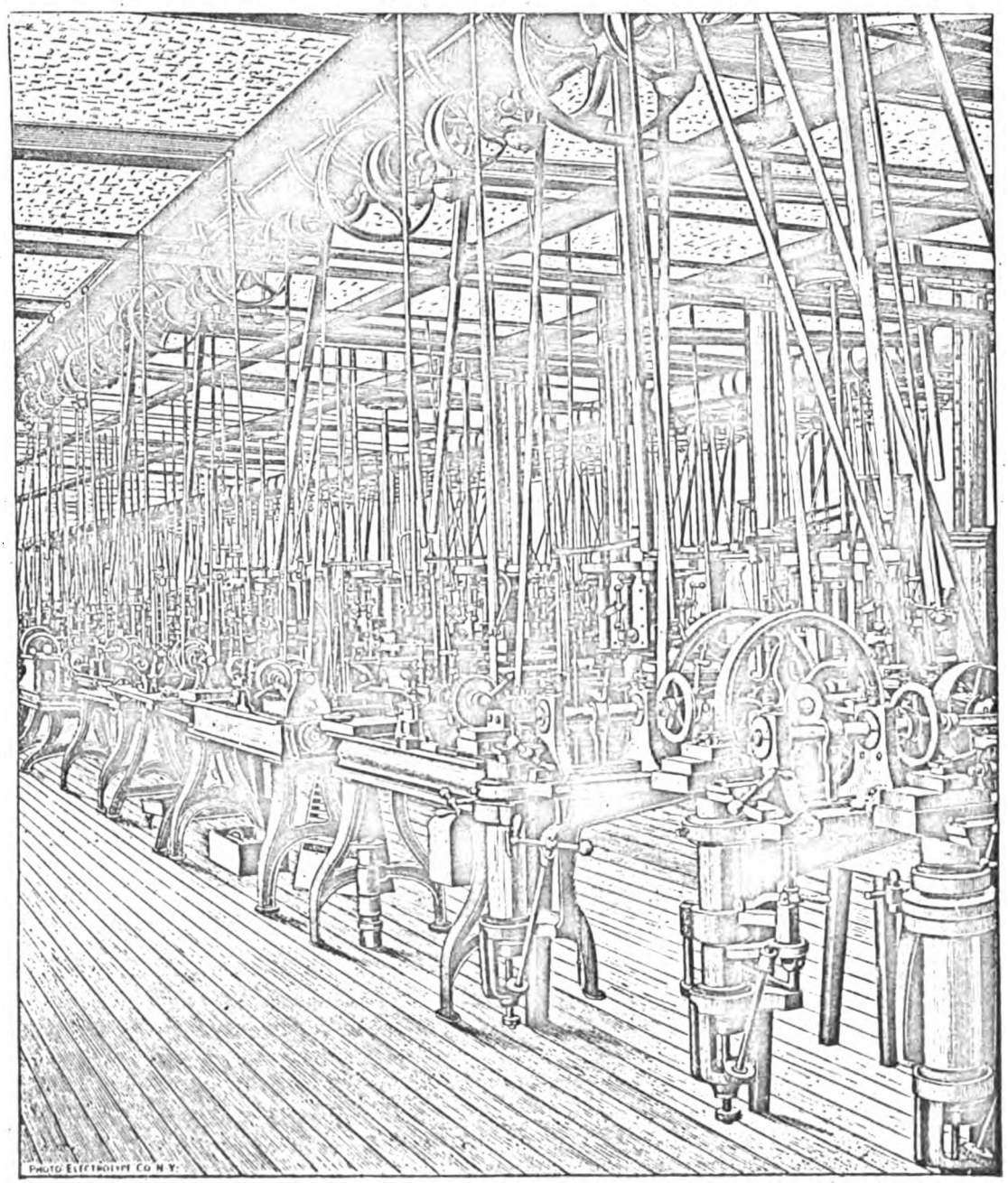

Fig. 22.

foreground, with small lathes back of them in the front row, and behind these a row of the Root jigging or profiling machines, with vertical shafts. But to get an adequate idea of the machine-shops of any one of our large fire-arms factories we must expand the small area which may be shown in such a view into acres of floor-space thickly set with similar machinery.

In an example of practice, nine machines (including milling, profiling, broaching, and drilling machines) were used in shaping a common pistol hammer. The milling operations upon the flat hammer, shown as a drop-forging in a previous illustration, might, after trimming, be as follows: Designating the main part of the forging as the body, and the three upper projections as the head and upper and lower combs, there would be two side cuts, an edge cut at some convenient spot (according to the arrangements of the holders and fixtures) to furnish a bearing or basis for subsequent cuts, an edge cut on the front of head and body, an edge cut under head, an edge cut on top of upper comb, and an edge cut between the combs. The lower part of the body and the under side of the lower comb, and perhaps the top of the upper comb, might be finished by edging cuts upon a profiling-machine. In milling, a single cut usually finishes the surface ready for grinding or bufling, but roughing and finishing cuts are sometimes made, especially where much metal has to be removed, and in bearing parts, where great nicety is to be obtained. In profiling, two cuts—roughing and finishing—are more usual, as the milling-cutter is then subject to greater variations of work, and does not usually make as smooth a cut. Profiling cuts save a greater number of milling cuts, and the expense of many irregular milling-cutters; but they are not generally available for such cuts as that between the combs, or under the head, where there are re-entering angles, nor are they desirable for flat and nearly flat cuts, such as those upon the sides and front edge of the hammer, which may be better and more steadily executed in a milling-machine. Cuts may often be saved in number, if desirable, by the use of mills of more irregular forms, but the expense of making these and keeping them true to gauge may render it undesirable. This expense is, however, reduced by the use of the milling-cutters for irregular forms made by the Brown & Sharp Manufacturing Company, of which an example is shown in the illustration (Fig. 23). These are made on a system which admits of exact duplication in the cutters (important for interchangeable work), and they may be sharpened by grinding without changing the form. Ordinary cutters, after becoming drilled, require to be annealed, recut, and rehardened at considerable cost.

Fig. 23.

Where two opposite faces of a piece are to be milled, whether they be parallel or at a slight angle, the two operations may be performed at once by a double-head face-milling machine. Such a machine for milling the lock-frame of the Colt revolver is shown in the illustration (Fig. 24). In this there are two face mills, which may be adjusted (with their spindles) so as to make a slight angle with each other. The spindles and the sliding tables, with the screw-feed for moving the cutters forward and back, are adjustable at an angle on vertical pivots. A side fixture holds the lock-frame, by means of a clamp, during the performance of work upon it. The machine is shown rigged with oil-tank, drip-pan, and oil-pump, with driving gear. A double face milling-machine of a different description is sometimes used on the light work of facing triggers. In this there are two face mills, one on a fixed and one on a sliding head, and neither of them revolves. A pin set in the center of the fixed mill holds the trigger, in which the hole has been previously drilled, and a revolving arm, with a projecting pin or finger coming against the trigger, forces it around in rapid revolution.

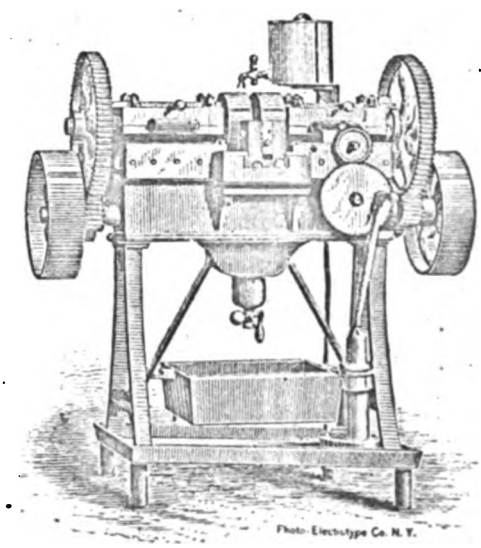

Fig. 24.

The milling-machine was of earlier introduction than the planer. Milling, or, as they were called, slabbing machines, were used for making narrow plane surfaces, while broader ones were made by chipping and filing. But while the principle may be considered indefinitely old, its introduction as a great industrial factor in gun-making was approached by slow and awkward steps.

Colonel North, at Middletown, Connecticut, is stated to have used milling-machines, with cutters of irregular form for milling the pan and between the bolsters in the flint-lock musket, prior to 1817, and they are stated to have been used at Harper's Ferry and at Whitneyville at early dates. The iron-cutting machines used by Hall at Harper's Ferry prior to 1827 did with cutters and saws work usually done elsewhere with grindstones, chisels, and files. A milling and drilling machine was used for milling screw-pins, as well as for drilling, reaming, and countersinking holes. This had a screw adjustment and conical sockets. A straight cutting machine was used, which appears to have been a milling-machine, for the production of flat and fluted surfaces, and which, as was then suggested, might have been applied to the milling of irregular forms. A lever cutting machine was used for mortising through the receiver for the cock and for boring the pan, and appears to have been similar in operation to some forms of hand-milling machine now in use. A curve cutting machine was used, which was probably a bridge-milling machine, or a lathe with a former. There was thus at Hall's works a small plant of milling machinery by which the system and economy of the manufacture was somewhat altered. By these machines, however, it is stated that there was obtained in 1827 an efficiency of only one-third greater than by filing—an improvement which does not appear large

from the present standpoint. The machinery was, however, excessively solid and heavy, and was run by hand. In 1836 we find that Middletown contractors, who had commenced the manufacture of Hall's rifles, and had made milling, drilling, and edging machines of some sort, were making the rifles at a contract price of about $4 per stand less than the cost to the government with Hall's machinery.

At the Springfield armory milling and edging machinery was not introduced until a more recent date. The first milling-machine used in Springfield is said to have been a fixed-spindle machine used for rough flat-milling monkey-wrenches in 1834. About this time Thomas Warner, at the United States armory, devised a plain milling-machine to make lock-plates of uniform thickness. This class of machinery was then known to have been in use at Middletown, for the master-armorer at the Springfield armory sent there in 1835 to get a Mr. Barker to build a milling-machine. In this machine the cutter-spindle was adjusted at a distance above the work by being carried by a lever movable (with a screw adjustment) about the spindle from which the power was obtained. About 1830 Ethan Allen is stated to have devised the method of using cutters of irregular outline for milling the forms of pistol-locks. A small fixed-spindle milling-machine is still to be seen at the Whitneyville armory, and, although of uncertain date, is said to have been built by Eli Whitney, sr. This has a work-plate with a power-screw feed actuated by a worm gear, so as to disengage at the end of the cut by the dropping of a screw-spindle—a method still applied in machines of the present day. Soon after the introduction of plain milling machinery at Springfield Messrs. Robbins & Flagg, contractors at the Waters' armory at Millbury, built a machine for milling the irregular edges of lock-plates. This worked well, and was introduced at the Springfield armory. Other devices for milling were also introduced, and in 1840, under Thomas Warner, milling-machines were built with spindles adjustable in vertical slides, as at present. Five machines were at first built, comprising, with their fixtures, a complete set for finishing the bayonet in all its parts, dispensing with grinding and greatly reducing the labor required. These machines had power-screw feed and disengaging gear, and their predecessors at the Springfield armory are described as temporary fixtures, rigged upon lathes and generally of rude construction. The first milling-machine used in Hartford, Connecticut, is said to have been brought there by Mr. R. S. Lawrence, who took an important

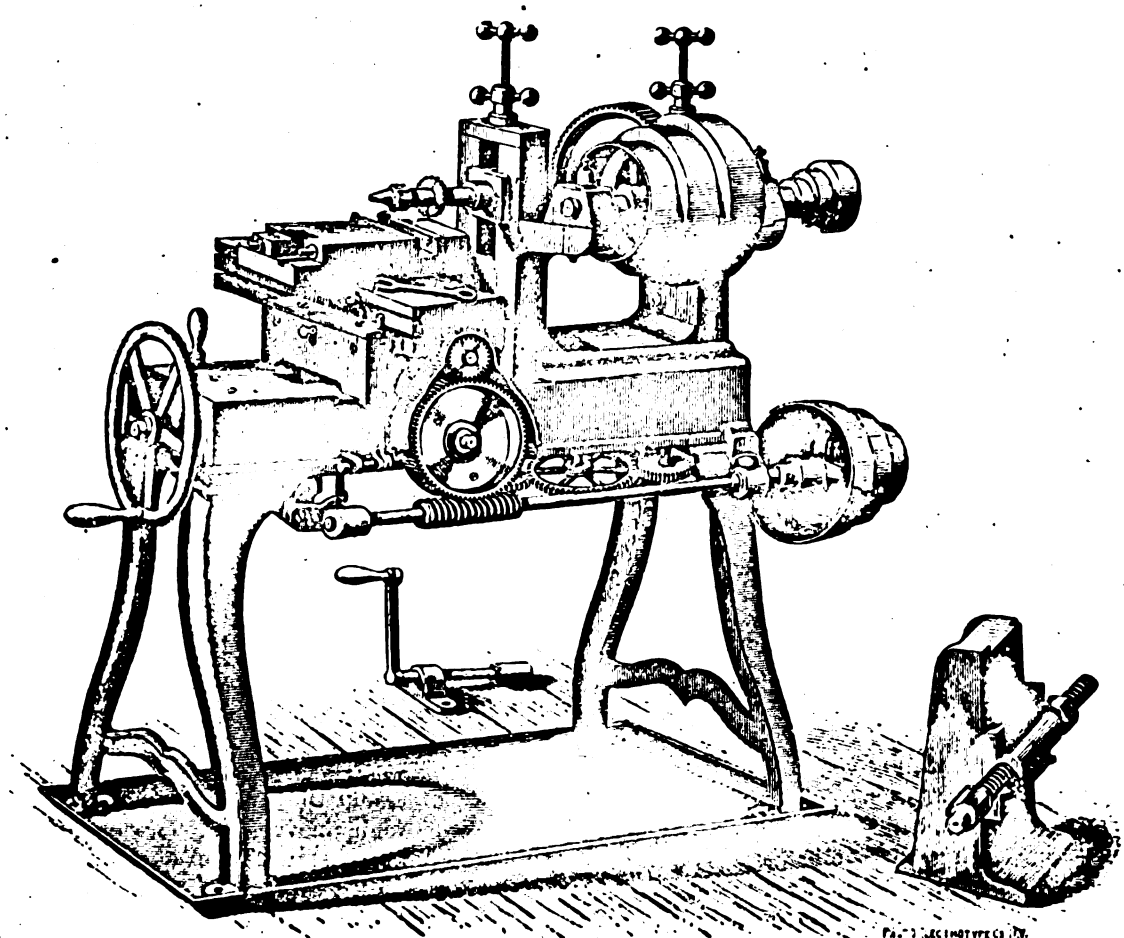

Fig. 25.

part in the development of improved gun machinery, both by his own designs and by his efforts to combine the best appliances then known; a policy finding expression in many features of the improved machinery built at Windsor, Vermont, about 1850. The general manufacture of milling-machines dates back only twenty-five or thirty

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years, and twenty years ago there were but three extensive manufacturers of milling-machines. The demand for them in the rapid growth of gun and sewing-machine manufacture after 1855 was very largely supplied by George S. Lincoln & Co., of Hartford, the Lincoln pattern being a well-known and standard machine, of which an illustration is here given (Fig. 25). This machine is provided with back gear. It was designed by F. A. Pratt, who afterward improved it by substituting a screw-feed in place of the rack-feed in the original design. It is considered that since 1855 nearly 100,000 of these machines, or practical copies of them, have been built for gun, sewing-machine, and similar work. When we attempt to consider the labor that would be required to be done by filing and chiseling the work that has been done by these machines, we see the utter futility of attempting comparison between hand and machine work for certain classes of labor-saving machinery. The Lincoln machines were from the outset, in 1854–'55, made in large lots, with interchangeable parts, and some of them have been in active use for nearly a quarter of a century.

Where the heaviness of the work requires greater provision for steadiness, the cutter-spindle is provided with a bearing at the outer end, which would otherwise overhang. This bearing is supported by a tail-stock on one side or at the end of the bed, or by a heavy arm of the frame extending over the spindle, which arrangement may admit of greater convenience in handling the work.

As an illustration of the care that is exercised in the production of a fine quality of interchangeable work, it may be stated that at the Smith & Wesson pistol factory it is the custom to run the milling-machines before working until the spindles become heated, and the same conditions of bearing are thus established at the outset as would result in the later process of the work.

PROFILING.—The distinction between milling and edging or profiling machines is not clearly drawn, bridge-milling being, in effect, simply a method of edging by means of a fixture upon a milling-machine, the operation being as follows: The cutting-mill revolves upon a spindle fixed in position, and the work is clamped to a long holder, pivoted as far from the cutter as convenient, but upon a movable carriage. The bridge is a fixed fulcrum directly under the cutter, and the pattern to be cut forms the under side of the holder, which, with the work, passing between the cutter and the bridge, and resting upon the bridge, is lifted and lowered conformably to the pattern, while the cutter mills a corresponding outline in the work above. This, the earliest form of profiling, does not admit of convenient application to many forms which may be cut in the machine more distinctively known as the profiling-machine, but it is still much used in edging butt-plates and other pieces whose surfaces have large radii of curvature.

Profiling-machines are specially used in making rounding cuts of surfaces curved in every plane section, as only surfaces curved in one plane can be cut by irregular-formed milling-cutters, acting in connection with plane slides, without formers. They are also used in cutting around closed curves, whether plane or not, which, if interior, could not be cut in a milling-machine, and if exterior, could only be so cut by a series of cutters and by a succession of operations. Profiling-machines are used to advantage, not only in cutting the curves of bands, guards, straps, and other parts having long, closed, or re-entering curves, but they are also useful in making many small chamfering cuts upon the edges of rounded surfaces. The cutter upon the profiling-machine is usually of necessity upon a light spindle in a movable frame, while the cutter of the milling-machine is mounted on a very heavy spindle, in very heavy and rigid bearings. The profiling cutter may also be at one moment edging a sharp convex curve and at the next may be nearly sunk in the work. The cut is therefore less steady and smooth than the milling-machine cut.

In the ordinary profiling-machine the table has a horizontal rack and pinion traverse. The gearing is made double to take up back-lash. There are two upright cutter-spindles, with guide-pins, in a frame which may be made to slide vertically and horizontally, the vertical movement being used in adjusting the height of the cutters and the guide-pins and in bringing them down to the work upon the table. The vertical spindles are belted to a long horizontal drum at the back of the machine, and by the simultaneous action of the table and cross-slide movements the guide-pins may be held to a former, while the cutters describe and edge a similar form, the cutters being used respectively for roughing and finishing cuts, the piece to be operated upon remaining clamped while the cutter-spindles are shifted by the cross-slide traverse from roughing to finishing. As an example of the work upon such a machine, it may be said that 150 trigger-guards a day may be edged upon it—outside and in—rough and finish cuts.

These machines are simply bedding machines applied to metal work. At some of the armories, in 1845, prior to their introduction, it was customary to put side-plates, guard-plates, and the like upon a stocking-machine for edging. The machine not being sufficiently firm for this work, made a rough, uneven cut, which had to be filed down. The straight-slide edging or profiling machine, with two spindles, and substantially as shown in the illustration (Fig. 26), was designed in 1848 by F. W. Howe for Robbins & Lawrence, of Windsor, Vermont. This machine had double gearing for the feed motions, one set of gears being half a tooth forward, so as to take up back-lash and insure greater continuity of motion. The former was of the same outline as the piece shaped, and two successive cuts, roughing and finishing, could be given the piece without moving it from its position, the cutter-spindles being shifted.

An edging-machine, in which four spindles were grouped about a center, was designed by E. K. Root for the work on Colt's revolvers. This is commonly called a jigging-machine. The power is derived from a vertical spindle,

around which the cutter-spindles may be shifted in rotation. They are lowered to the work by handles with gears, which actuate vertical racks, and one or both of the feed motions is furnished by slides in the bed. The formers used cannot be of the same pattern as the piece cut unless double slides are rigged upon the bed and all the motions obtained from them. It may be used for making four successive profiling cuts upon a single piece, or in making single independent cuts upon four different pieces.

Tip-turning or oval-cutting machines, sometimes used, are in principle profiling-machines. Two steel tips are turned at once, being clamped together on the power-spindle and forming an oval. A carriage, bearing a guide-disk and a milling-cutter, either rests entirely on springs, and has a universal movement, or moves in a slide, and is pressed by springs in only one direction. The carriage-plate bears the cutter and the guide-disk upon horizontal spindles, placed at an angle with the power-spindle, upon which the work and the pattern are set. The movement and tendency of the carriage at once presses the guide-disk against the pattern form, and the cutter against the work.

On the account-books for piece-work at the Springfield armory the first entry for work on a metal-profiling machine appears in 1849, and for work on an edging-machine in 1853. The drawings of the edging-machine in use at Sharp's rifle works, Hartford, were taken to Cyrus Buckland, at the Springfield armory, by a United States government inspector in 1852. This machine was of the same pattern as those supplied by Robbins & Lawrence to the British government.

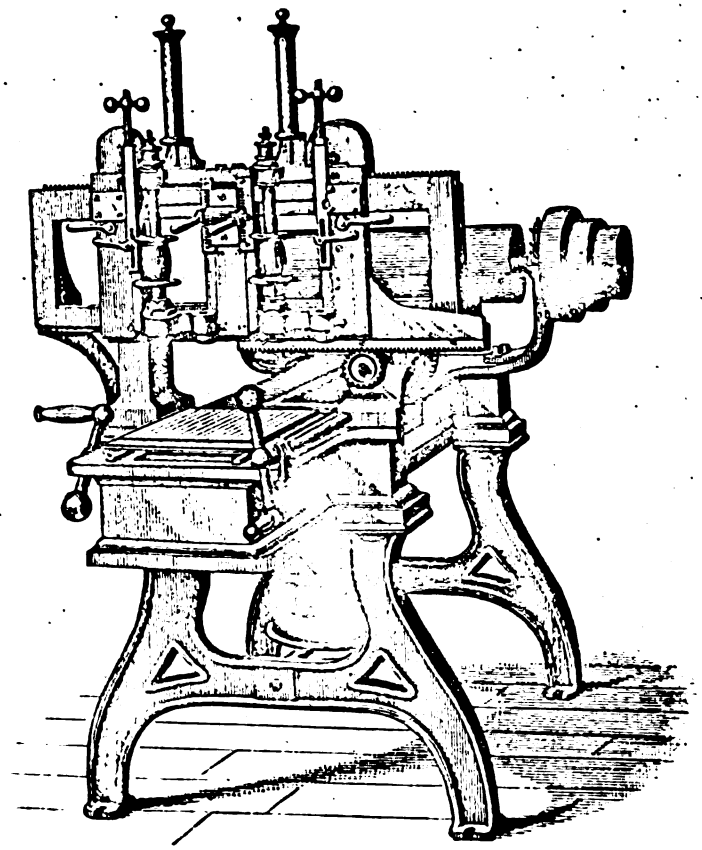

Fig. 26.

Automatic gearing, to displace the hand-feed in holding the cutter to its work, was designed by Cyrus Buckland, and was used at the Springfield armory to a limited extent. Similar mechanism, designed by Frederick W. Howe, was used with advantage in edging lock-plates by the Providence Tool Company in 1861.

DRILLING AND CHUCKING.—In drilling, pieces requiring a number of holes to be drilled, countersunk, or the like are placed in a jig, commonly a hinged clamp of two plates, in which the position of the work is determined by pins in the lower plate, the upper plate containing hardened drill bearings; and the work is done in multi-spindle drill presses.

A machine for performing a series of drilling, boring, or kindred operations, by having the tools or the pieces of work, or both, brought into position and stopped at proper intervals by rotation in holders, is commonly called a chucking-machine. For small barrels, tubes, bolts, bayonet-sockets, base-pins, and chambers these machines greatly facilitate the work to be done by obviating the necessity for frequent removal and resetting of the pieces. For example, a large bolt for a magazine gun is operated upon by 14 tools in a horizontal chucking lathe, 25 to 30 bolts being thus finished by a man in 10 hours—an average of about 1¼ minutes per operation. But chucking-machines are almost indispensable in operations upon the cylinders of revolvers. In one form of "Colt" chucking-machines for drilling, reaming, and boring revolver cylinders the work is held in a chuck on the power-spindle, while the tools, set in rods with bits, are chucked into position before the work, a hook, with rack and pinion feed, serving to push them up to, and remove them from, the work. The cone-seating machine differs from the foregoing in that the drills and tools both chuck into position and have an independent rotation, engaging with a power-spindle, while the work (a revolver cylinder) is simply chucked, not moving during the cut.

A form of horizontal chucking lathe is here illustrated (Fig. 27). In this the work revolves upon a spindle. A cluster of tools is turned by means of a small handle with a spring and ratchet movement, and a hook rests in a groove at the back end of the uppermost tool-holder, making connection with a rack in the same line, and the tool is operated by being thus advanced or withdrawn by a gear on a spindle, which, as shown, is turned by three handles, or otherwise by a hand wheel. If the movement of the tools is about a vertical spindle, the machine is called a turret lathe. In 1852 E. K. Root, at Colt's armory, devised a double-turret machine for centering, center-drilling, and squaring up base-pins, in which the work revolved horizontally between two turrets or tool-stocks, which chucked about vertical centers, and operations were thus performed upon both ends of the work. It is noteworthy that the same arrangement of parts characteristic of the Colt revolver seems to have been carried through the principal

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machines for its manufacture, the horizontal chucking lathes, cone-seating and screw machines, barrel-boring, profiling, and mortising machines, and even the compound crank-drops, exhibiting the same general arrangement of working parts about a center.

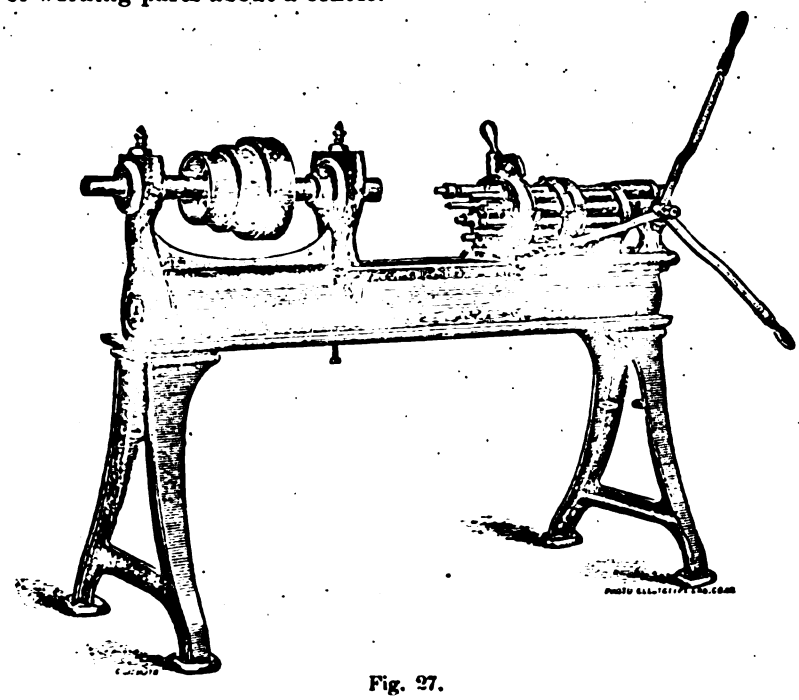

Fig. 27.

SCREW MAKING.—Screw-making machines, of which many desirable forms are manufactured, are generally turret lathes. Of most systems of guns or pistols the screws number over one-fourth of the whole number of parts, and screws and pins about a third. The making of these is facilitated by the revolving tool-stock. Even with a hand-fed turret lathe working on large screws one man can make as many screws as four or five men with engine lathes and chasers. With the most rapid-acting power-fed machines, cutting small screws from the wire, the production is very great, one machine turning out from 250 (in case of a complicated shape with a milled head) to 4,200 screws a day without slotting, and one boy being capable of tending from 8 to 18 machines; an improvement in productive efficiency per operative of from ten to twenty fold as compared with methods commonly in use for this class of work in 1870. The turret lathe is simply an efficient combination of gauging, turning, threading, stamping, pointing, and cutting-off machinery, saving the time of setting and handling the pieces between these operations. A machine so prolific as the automatic-feed machine, if employed continuously upon screws of a single size, would soon outrun the requirements, not only of a small, but of a large establishment, and the necessity for cutting many sizes of screws, for the use of several sizes of machines and for close gauging (requiring the dies and tools to be carefully watched and changed when worn), is such that the simpler and less automatic machines may often be most suitable for ordinary use in a gun-shop.

The simple form of turret lathe, the tool-stock chucking by hand, shown in the illustration (Fig. 28), is stated to be the earliest turret screw machine made for general sale. It was designed in 1858 by H. D. Stone, of the Jones & Lamson Company, of Windsor, Vermont. This is of interest, since it is more especially within the last twenty years that labor-saving machinery, which may have long existed in devices of special and limited application, has been manufactured in large quantities for general sale.

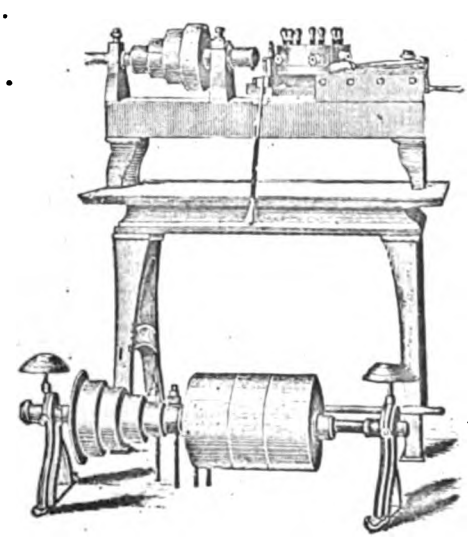

Fig. 28.

The slotting of screws is a brief operation, usually performed by a slotting mill, the screw being set in a socket and passed along the mill by the action of a hand lever.

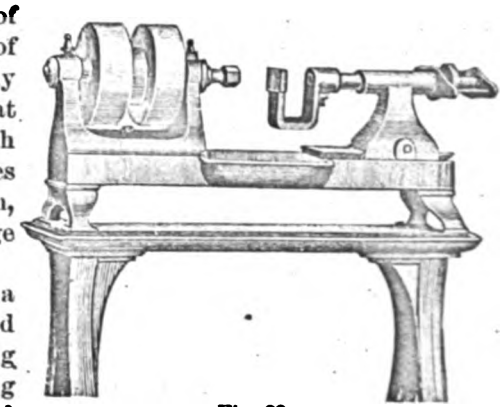

Fig. 29.

The tapping of small nuts may be done in a turret lathe, but a tapping machine or lathe is more generally used. The principal feature of these machines is the reversing gear, which, in the lathe shown in the illustration (Fig. 29), is a covered clutch between the spindles, operated by drawing back the piece. In upright machines the reversal is sometimes effected by a foot-lever. In the machinery used for tapping receivers and threading breech-screws for interchangeable work at the Springfield armory the threading is done with a leader screw and a chaser or follower-die, regulating the feed of the cutting tool, and the tapping machine is a form of horizontal chucking lathe with reversing gears.

Of the whole number of machines constituting a gun- or pistol-making plant, 4 or 5 per cent. will usually be for screw-making, comprising, beside three or four sizes of screw machines, slotting-machines, drill-presses, and machinery for special cuts required by the system. If too powerful a machine be used in cutting small screws, there is a liability to strip the thread.

TURNING.—As an example of a labor-saving contrivance in special turning may be cited the arrangement used at the Springfield armory for facing off bands, in which a lever serves to move up two cutting-off tools upon a carriage, separated at a distance determined by a stop, facing off both sides of the band at one operation. It is very common to see butt-plates turned, instead of being profiled or bridge-milled. In this case, the plates are clamped upon a center-piece, and the turning tool thus machines a number of them at a time, as though it were turning a single piece.

SLOTTING AND DRIFTING.—Slotting and broaching cuts are used in making holes and openings, which, on account of their depth or angular shape, cannot be milled or edged. The opening in the frame of the Colt revolver, through which plays a pawl called the hand, is an example of a cut requiring to be slotted. The body of the metal is first taken out by drilling a series of holes, and the opening is then slotted; the depth is then extended by deeper drilling, followed again by slotting, the tool in the machine used having a horizontal movement. The vertical revolving-head mortising machine is a form of slotting-machine here illustrated (Fig. 30), the machine being designed to obtain for slotting cuts the same economy and facility as is obtained in the turret and the horizontal chucking-machines for turning and threading cuts. The bed of the machine is mounted upon a balanced slide, having an up and down movement, and the tool is stationary during the operation, being held in a chucking tool-stock, so that four tools may be successively applied to the work upon the bed. A double slide upon the bed secures, with proper stops and jig frames, the position and extent of movement required for the work.

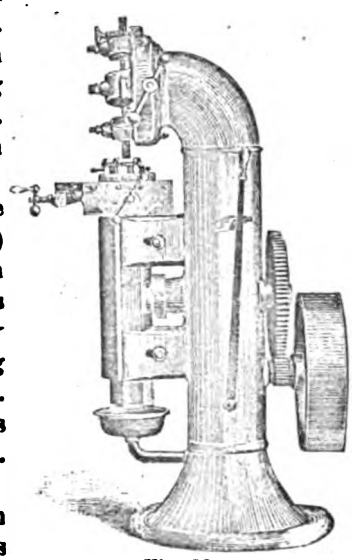

Fig. 30.

Through-mortises and openings of an angular form are usually broached, the broach being very slightly taper, or (depending upon the elasticity of the metal) without any appreciable taper, of the form of the opening, and banded about with a series of strong square-cutting edges. Broaches are sometimes as much as 8 inches deep, with 16 or 18 cutting edges. They are forced through the openings by heavy power-presses, smoothing and enlarging them as they pass through. By broaching or drifting, cuts are executed which could not be economically done in any other way. For example, in 1852, a mortise being required to be cut for the Sharp's rifle, it was estimated at the high cost of $1 50 each; but a broaching machine was built by Mr. R. S. Lawrence which "did the work" for 4 cents each.

FINISHING PROCESSES.—The small parts are polished upon emery wheels or upon leather-covered wheels spread with glue and surfaced with emery. These wheels sometimes have edges of special conformation for polishing peculiar forms, but are more usually flat wheels. The face-polishing machine is a flat, revolving plate covered with emery, upon which the pieces are pressed. We may estimate that 25 or 30 frames or lathes for polishing will be required for 100 rifles a day, and nearly in that ratio for a larger output.

Resort is had to brazing in a few cases where permanent fixtures, such as barrel lugs or sights, are placed upon a piece which may be better finished before they are made part of it. Some very interesting work in the reduction of bores by the insertion of tubes brazed-in has been done at the Springfield armory, and a considerable number of large-bore barrels from muzzle-loaders of 1842 were thus converted to the present size of bore. The practice was discontinued on economical grounds, and, though the barrels thus made were strong, from their lack of homogeneity they were considered inferior to solid steel barrels.

Acknowledgments.—In the preparation of the foregoing account acknowledgment is due the officers of the ordnance department for courtesies kindly extended, and more especially to Colonel J. G. Benton, commanding the national armory at Springfield, the detailed and thorough ordnance memoranda prepared by him leaving scarcely anything more to be said regarding the practice at the national armory. Acknowledgment for courtesies and assistance ought also to be made to Messrs. J. T. Ames, A. H. Waters, Thomas Warner, James H. Burton, Selah Goodrich, the late W. W. Winchester, General W. B. Franklin, R. S. Lawrence, Horace Lord, Philos Remington, and Eli Whitney.

I b.

AMMUNITION.

PART I b.—THE MANUFACTURE OF AMMUNITION.

TABLE II.—THE MANUFACTURE OF AMMUNITION IN THE UNITED STATES.(a)

State.	Number of establishments.	Capital.	Greatest number of hands employed at any one time during the year.	Average number of hands employed.			Total amount paid in wages during the year.	Materials.	Products.
				Males above 16 years.	Females above 15 years.	Children and youths.			
The United States	5	$834,000	1,176	508	558	17	$366,778	$1,238,452	$1,929,966
Connecticut	3	724,000	922	418	453	.....	303,519	1,108,852	1,706,852
Massachusetts	1	100,000	204	80	100	15	58,259	114,600	198,114
Delaware	1	10,000	50	10	5	2	5,000	15,000	25,000

a This table has reference mainly to the manufacture of ammunition for small fire-arms, not including the manufacture of cannon balls and shells, nor the crude manufactures of gunpowder and lead shot.

MACHINE PROCESSES AND THE DEVELOPMENT OF THE MANUFACTURE.

To the report on the manufacture of fire-arms is herewith appended a brief statement of that of ammunition—a manufacture naturally associated with the other, and the methods of which are distinctively American in their origin, and marked by great ingenuity, a wonderfully prolific output, and a quality surpassing anything approached by methods employed in foreign countries, or in any country prior to the past decade.

The nature of the manufacture is consistent with great productiveness, the parts to be made being few, and the processes being uninvolved with each other and establishing a natural system of procedure. The work is mostly press work, which is usually rapid, and permits the employment of unskilled or slightly skilled labor to a large extent, and without detriment to the accuracy of the work. Women are largely employed upon it, sometimes constituting over one-half of the whole number of operatives.

The ordinary copper percussion-cap was patented in 1822 by Joshua Shaw, who was in 1845 compensated by Congress in the sum of $20,000 for this valuable invention. But brass and copper shell cartridges did not come into use until some thirty years ago, when their importance in making gas-tight joints in breech-loading systems began to be recognized. The prominence which their manufacture has now attained in this country in supplying foreign nations with ammunition is due not only to the ingenuity which has developed the mechanical methods employed, but also to the purity and ductility of the American copper used in the manufacture.

From a statistical standpoint, the most noticeable difference between the manufacture of fire-arms and of metallic ammunition is that from the greater efficiency of the machinery the latter product involves less labor than the former, the value of the material being relatively greater. This difference is most strongly marked in the manufacture of lead shot and slugs, in which, speaking roundly, an added value of from one-tenth to one-fifth is given the material, while in the manufacture of fire-arms the value of the material is sometimes increased more than five-fold.

In the manufacture of ammunition on a large scale a considerable amount of capital is required in order to carry and to properly store and handle the costly and dangerous materials employed, but the value of capital required for the machine plant is relatively less for the manufacture of cartridges than for the manufacture of fire-arms.

A center-fire cartridge is composed of shell, anvil, inside cup, reinforcing, primer, and bullet, beside the powder and fulminate. The great majority of the mechanical operations are performed upon the shell, and power-presses for this work constitute the great majority of the machines. The shells are first cut and cupped from brass and copper sheets, one attendant to a press, one press having a daily capacity of from 40,000 to 120,000 shells, according to size. This operation is followed by annealing, pickling, and washing, repeated annealing being necessary to preserve the ductility of the metal.

Then follows the drawing, an operation which, from its repetitions and less rapidity, requires five times as many presses as the cutting and cupping. Cartridge shells are drawn from two to five times—generally three or four—according to size and material, the drawing being more rapid and less often repeated for the smaller shells, and less rapid for the later than for the earlier drawings. The large presses have an attendant each, but the smaller presses are often rigged with automatic feeders, so that one person can attend several. The shells are either set by the operative in a rotating plate, which passes under a punch, or else the automatic feed is effected by dropping them into the plate from a duct leading from a hopper or other receptacle. Annealing, with the subsequent pickling in a solution of sulphuric acid, and washing in a potash solution, usually intervene between the operations of drawing, the shell being annealed in perforated cylinders, subjected, while in rotation, to a furnace heat, and the washing-machines being inclined cylindrical vessels, in which the shells are tumbled and rinsed, after which they are dried at a moderate heat (125°).

The trimming and heading are executed upon the same machine for most sizes of cartridges, although separate trimming and heading presses are employed for heavier work, such as the cartridge shells for machine guns. The smaller presses are automatic, with one attendant for several machines, the larger hand-fed with one attendant each. The heading is usually done in presses acting horizontally. This method of heading is said to have been devised by Ethan Allen, of Allen & Wheelock, Worcester, Massachusetts, in 1859. His first machine was built upon a lathe-bed, and headed 60 to 80 cartridge shells a minute. The cartridge was dropped from above and taken upon a horizontal rod, operated by an eccentric upon a horizontal shaft. The rod carried the shell forward through an opening, when it was headed by a single blow, the rim being formed in a countersink about the opening, and the header being removed for the thrusting out of the headed shell, which was ejected by the next shell brought forward by the rod. At this time other parties headed cartridges by spinning up the cup—a slower process, and one liable to cause the shell to be thin at the center. The circle feed for trimming or cutting off was also used at this time.

Anviling is the insertion of the anvils, which are pressed into the shells by power-presses, the anvils being first cut and shaped in a quadruple press, making 4 anvils at a stroke, having one attendant, and turning out 150,000 anvils a day. The reinforcing rings of the head are inserted by power-presses in a similar manner, these being first cut, drawn, and trimmed.

In the nozzle-annealing, or annealing for the tapering, only a portion of the shell is annealed. The shells are set in plates, and by their movement are passed in procession between rows of gas-jets.

The next operation is the pricking or venting and priming, by which the primer is inserted, the daily capacity of a press for this work being upward of 40,000. Impressions in cups to receive fulminate are made at the rate of 80 a minute.

The first operation in the manufacture of primers is comprised in the cutting, cupping, and drawing in automatic-feed presses, one attendant to several presses, and each press having a capacity of upward of 40,000 a day. The next operation is varnishing. The apparatus for this work operates by dipping and dropping shellac from a great number of points, which is done automatically, an attendant being occupied in sifting the primers into feed-plates ready for the operation. The next operation is the priming proper, or charging the primer with fulminate, the placing of the primer in the shell being also called priming. The fulminate is in some cases spread upon feed-plates by hand, and dropped through holes in the feed-plates into the primers, set in corresponding plates, upon the withdrawal of an intervening plate. The attendant is occupied in spreading the fulminate. Then follows the operation of foil-pressing. The foil is pressed upon a row of primers at one operation, and the capacity per machine is upward of 150,000 per day, one attendant to three or four machines. An ingenious form of automatic machine is made to perform the work of charging the primer and priming the shell at the rate of 35 a minute. This is in principle like a vertical chucking-machine, the parts between which action ensues passing over and under each other and pausing during reciprocating movements, by which the fulminate is transported from a magazine and pressed down into the shells.

The shell thus charged and furnished is next generally tapered, one tapering press, with one attendant, having a capacity of 20,000 a day. Burring and trimming in presses and polishing in lathes are additional operations performed upon certain classes of fine and large shells.

After inspection and gauging, the shells are loaded with powder and bullet. The loading machinery is especially ingenious, the powder being held in a funnel-shaped receiver and dropped by charges into the shell; and, being pressed down by a rod or piston, it is so contrived that if, from any cause, the charge is too great, one bell rings, and if the charge is too small, another bell rings, thus warning the attendants and insuring the uniformity of the charge. One loading machine, with two attendants, has a capacity of 25,000 a day.

The slug or bullet then inserted is sometimes formed from cylindrical bars at the rate of 50 per minute, or else is cast, slug furnaces and apparatus being used, two attendants each, and the capacity per furnace being upward of 50,000 a day. The slugs are cast in hand-molds of 18 to 25 slugs at a time. They are then passed through swaging or bullet-forming presses, which are or may be automatic, in which case one man can attend as many as nine machines, the slugs being fed to them out of hoppers or receivers. They are then jigged—a term used to designate the placing of the bullets in feed-plates—which is done partly by hand, but assisted by machinery, which imparts a vibratory motion to the plates. This is preparatory to what is called channel-rolling, the jigging being for the purpose of

placing the bullets all upright and in position, so that they may be placed upon a revolving plate, which carries them through a channel between cutters, which groove the bullet. One such machine has a daily capacity of upward of 100,000 bullets, and one man attends three machines. Certain grades of bullets are now passed through an extra close-gauge trimming press, and the bullets are gauged and inspected.

The next operation is bullet-patching, or covering the rifle bullets with paper, to prevent the clogging of the grooves of the barrel with lead. This is sometimes done by hand, sometimes by machinery. In the bullet-patching machine the bullets are fed to the machine by hand, and the patch is presented to the bullet and secured by a minute drop of mucilage, fed automatically, and is rolled closely around the bullet, and the end is folded up by the friction of flexible rolls, 45 or 50 bullets being patched in a minute, and, including stoppages, full 20,000 in ten hours. Two attendants are required.

After the loading of the shell, it is crimped into the grooves of the bullet, and the cartridges are tumbled in sawdust and lubricated by sifting upon feed-plates and dipping, or otherwise the lubrication is performed by machinery, which forces the lubricant into the bullet grooves through the perforations of cylinders through which the bullets are passed. In the early introduction of breech-loading guns naked bullets were used, which clogged up the bore. In 1851, at the time of the visit of Kossuth to this country, R. S. Lawrence, who was making the Jennings rifles at Windsor, Vermont, was telegraphed by Mr. Cortlandt C. Palmer to come to New York and bring a breech-loading gun that would hit a man 10 times out of 25 at 500 yards. On the trial, which took place at Ravenswood, near Astoria, Long Island, after a few shots, the bullets struck 10 or 15 rods from the mark, the lead building up and fouling the bore. But next morning Lawrence tried lubricating the bullets with tallow, having previously grooved them, when at the second trial he was able to hit the mark two times out of three continuously. Mr. C. P. Dixon ordered a box of the lubricated bullets, and within fifteen days they had been sent to Paris, France, and immediately after came into general use.

Cartridges are found to deteriorate from the chemical action between the salts of the gunpowder and the material of the shells. This is prevented by coating the shells with an impermeable elastic varnish, which is effected by one of the most ingenious automatic machines used in the manufacture. The shells are placed in a hopper, and the arrangement for feeding is similar to that in the automatic wood-screw machines, the cartridge shells being picked up by hooked arms and delivered to a tubular duct, from which they are placed in chucks and varnished. The shells, after the varnishing, pass around a large circular disc or wheel, holding 40 shells, all set in chucks, which rotate, causing the varnish to set uniformly. All the operations performed are entirely automatic, one operative attending as many as three machines, supplying the reservoirs for shells and varnish, and exercising a general oversight. The hopper holds several hundred shells at a time. Forty shells at a time are in process of passing through the machine, which, with a product of 2,000 varnished shells per machine per hour, or 60,000 per operative per day, gives 1 minute 15 seconds for the time for the varnish to set in rotation, it being afterward thoroughly dried and hardened. The Pratt & Whitney Company have supplied these machines to a number of foreign governments, twenty machines to the French government alone.

Rim-fire cartridges have the priming contained in the rim, instead of having a separate primer inserted. Their manufacture is therefore more simple than that of center-fire cartridges. After the heading of the shells they are primed with fulminate, loaded with powder and bullet, crimped, tumbled, lubricated, and packed. In the operation of priming rim-fire cartridges the average number of attendants per machine is less than 1 to 5, and each machine has a daily capacity of 60,000 to 70,000. The loading with powder and bullet is done in presses with multiple presser-plates, one plate containing the shells and another the charges, which are thus pressed together in large numbers, 60,000 to 100,000 cartridges a day being loaded by one press, attended by one man with two girls, who prepare the plates.

In the manufacture of ammunition each separate product may be considered to constitute a separate branch of manufacture, which may be traced from beginning to end without indistinctness or confusion with any other part of the work. Thus the manufacture either of caps or of paper shells constitutes a complete and separate system by itself. The process of making caps is similar to that of making primers. They are first cut and formed in a press, 150,000 a day, 4 at a stroke, with one attendant. The trimming is done by automatic machinery, 4 or 5 machines to an attendant, and the caps are then varnished, a long row of them at one operation; the fulminate is dropped into the cap from multiple feed-plates, and the foil is pressed down over it, a long row of caps being completed at every stroke of the press.

In the manufacture of paper shells the paper is first cut into sheets the length of four shells. It is then pasted and rolled by hand. From the tubes thus formed the body of the shell is then pressed to size and cut up into lengths, the reinforcing being formed in a similar manner. The wads are rolled by special machines and formed in a press, and a succession of presses is used for inserting wad into reinforcing, reinforcing into body, and body into brass case. The brass head is then inserted, and the shell is primed. The presses for the last six operations mentioned have a capacity each of about 40,000 a day.